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THESIS

A COMPREHENSIVE SYSTEMS TESTING PLAN FOR THE SMART PHONE ASSISTED RAPID COMMUNICATION AND CONTROL SYSTEM (SPARCCS)
by
Donna A. Dulo
September 2012
Thesis Co-Advisors: Gurminder Singh, John H. Gibson

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13. ABSTRACT (maximum 200 words)

The Smart Phone Assisted Rapid Communication and Control System (SPARCCS) is a mobile device based wireless system that enables rapid communications in the military field or during civilian emergency operations by facilitating teams to capture images and share information with one another and with a central command and control center. This thesis contains a test plan and implementation of the plan for the SPARCCS system as well as a formal technical analysis of the system to ensure the proper operation, verification, and validation of the initial SPARCCS functional system. The SPARCCS system and the various wireless technologies upon which the system operates are thoroughly tested in various field and live settings to simulate real-world military and emergency services operations. The tests are designed to determine the optimal configurations of SPARCCS as well as the optimal wireless technologies to be used with SPARCCS for various operational situations. The results of this thesis shall be applied to the SPARCCS system to enable it to function properly in the operational environment.

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A COMPREHENSIVE SYSTEMS TESTING PLAN FOR THE SMART PHONE ASSISTED RAPID COMMUNICATION AND CONTROL SYSTEM (SPARCCS)

Donna A. Dulo
GS-12, U.S. Department of Army
B.S., U.S. Coast Guard Academy, University of the State of New York, 1993

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requirements for the degree of

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NAVAL POSTGRADUATE SCHOOL
September 2012

Author: Donna A. Dulo

Approved by: Gurminder Singh
Thesis Co-Advisor

John H. Gibson
Thesis Co-Advisor

Peter Denning
Chair, Department of Computer Science

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ABSTRACT

The Smart Phone Assisted Rapid Communication and Control System (SPARCCS) is a mobile device based wireless system that enables rapid communications in the military field or during civilian emergency operations by facilitating teams to capture images and share information with one another and with a central command and control center. This thesis contains a test plan and implementation of the plan for the SPARCCS system as well as a formal technical analysis of the system to ensure the proper operation, verification, and validation of the initial SPARCCS functional system. The SPARCCS system and the various wireless technologies upon which the system operates are thoroughly tested in various field and live settings to simulate real-world military and emergency services operations. The tests are designed to determine the optimal configurations of SPARCCS as well as the optimal wireless technologies to be used with SPARCCS for various operational situations. The results of this thesis shall be applied to the SPARCCS system to enable it to function properly in the operational environment

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LIST OF ACRONYMS AND ABBREVIATIONS

API	Application Programming Interface
BGAN	Broadband Global Area Network
C2	Command and Control
CI	Confidence Interval
CTL	Controlled Test Laboratory
EMS	Emergency Medical Services
GPS	Global Positioning System
LOC	Level of Confidence
OS	Operating System
POI	Point of Interest
SPARCCS	Smart Phone Assisted Rapid Communication and Control System
UAV	Unmanned Aerial Vehicle
VCRM	Verification Cross Reference Matrix
WIFI	Wireless Fidelity
WIMAX	Worldwide Interoperability for Microwave Access

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I. INTRODUCTION

A. SYSTEM INTRODUCTION

The Smart Phone Assisted Rapid Communication and Control System (SPARCCS) is a system in development in the Computer Science Department of the Naval Postgraduate School. The system is designed to enable rapid communications in the military field or during civilian emergency operations by facilitating teams with mobile devices to capture images and share information with one another and with a central command and control center.

The system is currently in development. The initial architecture was developed by Asche and Crews (2012) enabling a smart phone to communicate with the server and upload information and images. The system is functional at this initial stage of development.

B. PROBLEM STATEMENT

The SPARCCS system has had no formal testing since its inception. As a result, the system is at risk while it enters into later stages of development. Problems in systems discovered late in the development stage are exponentially more expensive to fix in terms of time, money, and resources. As a result, the SPARCCS system requires comprehensive testing at its current stage of development to help eliminate problems that may affect its reliability, availability, and safety.

C. RESEARCH DEPTH AND QUESTIONS

The research presented in this thesis will be the initial testing of the system, based on the preliminary development of the system as presented by Asche and Crews (March, 2012). At the time of the research in this thesis, the SPARCCS system has a preliminary foundation developed, including the basic web-based command center and the Android application for the mobile handheld devices that runs on Android smart phones and Android tablets.

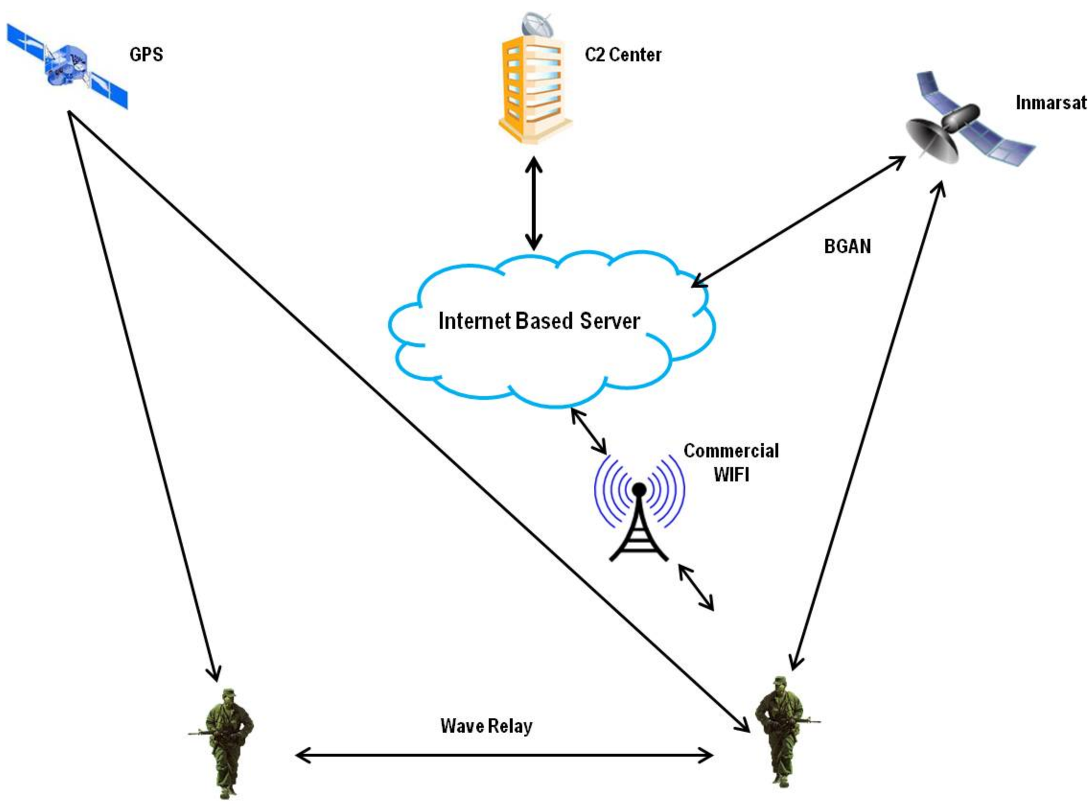

Figure 1. Test Domain of the Thesis

This thesis will test the current SPARCCS system with various wireless technologies such as WIFI, BGAN, and Wave Relay, as depicted in Figure 1 above. A variety of handheld devices such as smart phones and tablet PCs will be tested to demonstrate the application's performance on various

platforms. Additionally, several versions of the Android operating system, ranging from version 2.2 through version 4.0, will be tested.

The primary research questions for this thesis are:

1. What is an appropriate testing plan for the SPARCCS system and what are the results of the tests in the testing plan that can be used to evaluate and improve the system?

2. How can tests be used to evaluate the architecture and basic functionality of the SPARCCS system?

3. What tests are necessary to evaluate the SPARCCS and what are the results of those tests?

4. What future tests can be used on the system in the system's later development that would relate to the original test plan?

5. How can the SPARCCS system be analyzed to facilitate proper testing, verification and validation?

D. SYSTEM OVERVIEW

The overall system will consist of mobile users in a WIFI cloud with a team leader and a set of team members, all with smart phones. The team leaders will have their smart phones networked with the team members in the cloud. The team leaders will be able to connect to a satellite via

a BGAN connection and to a local server via technologies such as Persistent Systems Wave Relay radio-based router.

The server will communicate information to a command and control (C2) center. Additionally, a small UAV may be part of the field teams to facilitate airborne image taking and scanning which will give a broader picture of the operational area as well as communications relay. Each smart phone will have a small database. Each database will stay in synch with the master phone of the team leader. The team leader will then be able to send comprehensive situational information to the C2 center. The team leader will also be able to send information from the UAV to the C2 center.

The overall goal of the system is to be able to provide real-time information to a C2 center as to situational information in an area of operation to foster command and team situational awareness. This will promote rapid information transfer that will facilitate enhanced leadership decision-making and will help reduce operational decision cycles. Additionally, communication and data will be organized in a methodical manner facilitating strong communications and data exchange to promote incident and scene management and awareness.

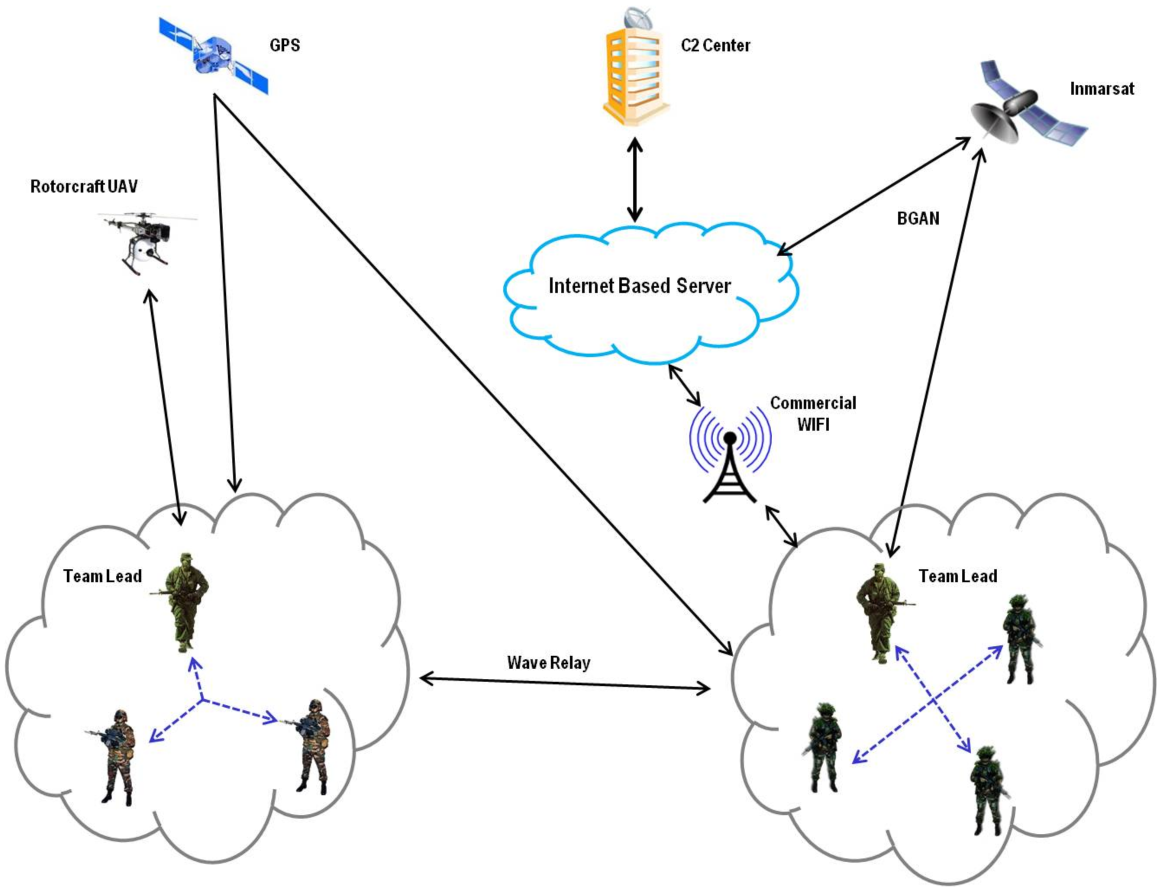

Figure 2. DoD OV-1 Diagram of the SPARCCS System

Various technologies will facilitate the communications cloud around the teams. The first technology is WIFI, which will be provided through a commercial wireless service. The second technology is a satellite Internet technology known as BGAN (Broadband Global Area Network), which is a proprietary satellite Internet service. BGAN uses the INMARSAT satellite constellation to facilitate Internet connectivity.

The third technology that will be tested is a Wave Relay system. This system consists of proprietary radio systems that act as both bridges and wireless hot spots that extend the range of WIFI clouds to distant teams using

the SPARCCS system. The Wave Relay technology, developed by Persistent Systems, will use the BGAN technology as the back-haul of its Internet connectivity. The final technology will be the WIMAX technology, a broadband wireless communications technology that acts as a bridge for wireless communications.

The overall goal of each technology is to sustain and maintain a viable WIFI cloud, with Internet reach-back, over the field teams to facilitate server and inter-team communications at all times.

E. SPARCCS SYSTEM CONTEXT DIAGRAM

A context diagram is a systems engineering-based diagram that provides an overview of a system by decomposing a system into its external entities and the products that are exchanged between the system and those entities (Kossiakoff & Sweet, 2011). The external entities are all of the entities that affect the system in some way, including the environment. The purpose of context diagrams is to highlight the entities that will interact with a system, including entities that provide maintenance, updates, and streams of data. Entities are any external influence, including other systems, media, and forms of support.

Context diagrams enable the analysis of a system by identifying the sources of data and information flows as well as the presence of power, commands, heat, weather, and so forth. Through the decomposition of these entities, a more complete picture of the system can be developed so

that the testing of the system can be optimized (Biemer, 2010). The context diagram of the SPARCCS system is presented in Figure 2.

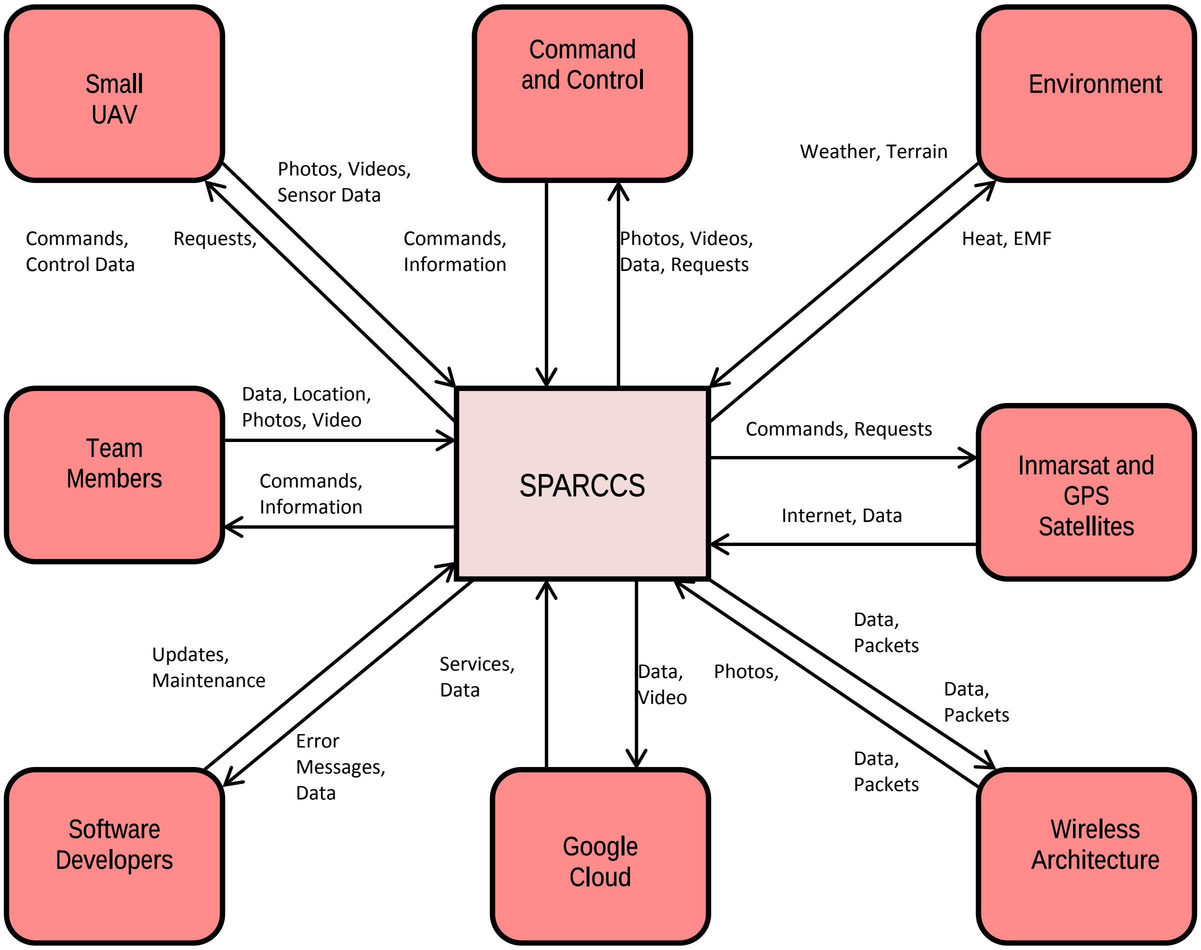

Figure 3. Context Diagram of the SPARCCS System

As can be seen in the context diagram, there are several key entities that interact with the SPARCCS system. Each entity must be considered in the testing program and the interactive products between the SPARCCS and the

external entities must also be a key part of the testing

program to ensure the viability, accuracy, and stability of those interactions.

F. CHAPTER SUMMARY

The test plan and implementation of the plan as well as the formal analysis of the system in this thesis will ensure the proper operation, verification, and validation of the SPARCCS system, which has currently been partially developed and is ready for initial architectural and systems testing. The SPARCCS testing will focus on performance and deployment testing to ensure system functionality in its current stage of development. The testing will also focus on the usability of the system including installation and user interface issues and capabilities.

G. THESIS STRUCTURE

The structure of this thesis roughly corresponds to a software systems engineering testing plan that would be performed in the operational environment in most DoD commercial and government systems development.

Chapter II describes the testing methodologies in detail and relates them to current best practices in the literature. It details wireless testing problems, the systems engineering testing paradigms for software testing, test design, test planning, and systems test partitioning. The concept of a controlled laboratory is also discussed. In addition, the principles of integration, interface and functional testing are explored, as are the concepts of performance and deployment testing, which are the central focus of the thesis. Finally, the principles of wireless

hardware and software testing are covered to round out the discussion. The chapter concludes with a brief on when to stop testing, an important concept in all engineering and systems testing programs.

Chapter III develops an integrated test plan for the SPARCCS system. It begins with a thorough requirements analysis for the specific scope of the system that will be tested in this thesis. The requirements are placed in a VCRM matrix, which is a requirements engineering tool for the management of system requirements. The test plan approach is then developed to demonstrate the comprehensive performance testing approach, the levels of testing and the various test environments. The chapter includes the qualification plan to ensure that the test plan and sequences are accurate and appropriate for the levels and scope of the required SPARCCS testing. The chapter develops the specific test cases, including the indoor and outdoor controlled testing as well as the field test plans for all of the required wireless technology. The chapter also describes in detail the test equipment and the wireless technology to be tested in the field tests. This chapter rounds out the description of the testing and equipment.

Chapter IV describes the results of the indoor and outdoor controlled testing and the results of the field testing of all of the technologies. It provides selected raw and analyzed data and explains the results of the tests in a systematic manner.

Chapter V provides the conclusions of the testing program. These are the high level results that will affect the continual development of the system as well as the operational plans of the system. These results will assist

in improving the system as it moves from the development to the implementation phase of its project cycle. The chapter provides final recommendations that can be applied to the system development and operational implementation to improve the system. In addition, the chapter provides areas for future testing and new technologies or new configurations of tested technologies that may help improve the system.

II. SPARCCS SYSTEM TESTING METHODOLOGY

This chapter describes the SPARCCS system testing methodologies in detail and relates them to current best practices in the literature. It details wireless testing problems, the systems engineering testing paradigms for software testing, test design, test planning and systems test partitioning. The concept of a controlled laboratory is also discussed. In addition, the principles of integration, interface and functional testing are explored, as are the concepts of performance and deployment testing, which are the central focus of the thesis. Finally, the principles of wireless hardware and software testing are covered. The chapter concludes with a brief on when to stop testing, an important concept in all engineering and systems testing programs.

A. INTRODUCTION TO SPARCCS SYSTEMS TESTING

Testing is critical in any system, but especially in a wireless system such as SPARCCS due to the complex software and data sensitive nature of the wireless system in addition to its integrated communications systems backbone (Viana, Maag, and Zaidi, 2011). In many complex software intensive systems, major problems can manifest at any point in its modules and systems, and therefore comprehensive testing is crucial (Jorgensen, 2002).

The SPARCCS system has several distinct sub-systems that need to be integrated and as such, architectural, systems, and integration testing are required to ensure that the system has a reliable construct. The SPARCCS

system has a wide array of modules and sub-systems, making the integration of them critical as well, which must be validated by testing.

Through rigorous testing, developers of future SPARCCS modules can eliminate the interface, architectural, and interoperability faults and errors, and thus future systems development will go smoother and be more reliable.

Wireless architectural and interoperability problems can include (Bell, Jung, & Krishnakumar, 2010; Nguyen, Waeselnck, & Riviere, 2008; & Zhifang, Bin, & Xiaopeng, 2010):

1. Incorrect interrupt handling
2. I/O Timing
3. Call to wrong/nonexistent procedure
4. Variable mismatch
5. Parameter mismatch
6. Incompatible data types
7. Hardware issues incompatibilities
8. Wireless communications incompatibilities
9. Protocol programming issues (TCI/IP)
10. Computational inconsistencies
11. GPS issues
12. Internet issues
13. System interface issues
14. Wireless protocol issues
15. User interface issues

As can be seen in the above list, major issues can take place at the architectural and interoperability level

(Giadrosich, 1995). Through rigorous testing, these issues can be detected and rectified before the system proceeds through its future development.

The SPARCCS system is in its development phase. The overall basic architecture has been developed. The testing plan will focus on the initial architecture to ensure that the architecture is viable and will function reliably as the foundation for future SPARCCS modules and systems. The testing plan will be developed and executed to ensure that the architectural foundation and current development of the system is technologically and architecturally sound for future development.

The testing process for the SPARCCS will be divided into three major components: hardware testing, software testing, and systems testing. Each area of testing is detailed in the sections below.

The testing of the SPARCCS system will be based on solid testing principles founded upon the systems engineering and computer science disciplines. By combining systems engineering and computer science testing principles, a more precise and well-rounded set of test results can be obtained to ensure real world accuracy and applicability of the test results (Kasser, 2007).

B. SYSTEMS ENGINEERING BASED TESTING

System testing is critical to ensure that the system functions properly, reliably and safely in terms of the system requirements and the system contract, proper safety criteria, and reliability requirements (Giadrosich, 1995). Testing helps reduce risks and helps assure proper human factors engineering in the system. It also helps to detect

problems and issues with the system, so that they can be rectified as early in the project as possible. Management of risks through testing helps in developing, producing, operating and sustaining the system and its capabilities. Testing helps ensure that system components meet their purpose and are in full compliance with their specifications (Jorgensen, 2002). Testing helps avoid system problems in the short term and long run.

1. Test Design

The test design seeks to ensure the design fulfills a need by the user/customer of the system. The user expects robust wireless communications performance from a system that is reliable, available, and that will perform well in complex environments. The functional flows of the system design demonstrate the key subsystem responsibilities, the interactions between the subsystems that provide critical test points for the testing plan (Kossiakoff & Sweet, 2011). Thus, functional analysis must be conducted on the system. For the SPARCCS system, functional analysis was conducted and the previous chapter includes the resulting analysis and diagrams of the system, as an introduction to the system.

System interfaces, modules, and subsystems can be tested more thoroughly and properly when design and testing plans are created in a systematic, well defined manner (Kossiakoff and Sweet, 2011). The interfaces, modules and subsystems are the major points of failure in complex systems, and therefore the designs of the system must be carefully developed by systems engineers and tested in the

same systematic manner with a careful consideration of the design and interactions of the interfaces, modules, and subsystems (Wasson, 2006).

2. Test Plans and Design

Test plans flow in parallel from the system test design. Multiple test plans can be developed and conducted simultaneously to ensure timeliness of the testing and to ensure that the testing scope and timeline keep the project on the critical path. From the test event timeline the test procedures are developed (Biemer, 2010).

As can be seen, both the design and the test plan flow in a hierarchical manner, with the test plan elements referring back to the design plan elements (Kossiakoff & Sweet, 2011). This parallel nature is critical in the testing of all system of systems to ensure that all aspects of the design are tested thoroughly and completely. As can be seen, this parallel nature of the system design and the test plan is systematic and thus a solid design coupled with a solid test plan will yield a positive outcome for the SPARCCS system future development. The need of the customer defines the specific capability to be fulfilled while the testing planning requirements determine the degree of sophistication of the test plans (Kasser, 2007).

Systems are inherently complex; the SPARCCS system is no exception. Through proper systems engineering test design, that carefully decomposes the system into smaller and smaller blocks, measures of effectiveness can be established so that testing processes can be developed and planned to ensure that each level of design, each building block, performs correctly and that the performance of that

block can be defined and measured through planned testing (Kossiakoff and Sweet, 2011). If a system is not tested in a systematic manner that parallels the design process, elements or interfaces may be missed in the testing process resulting in errors, faults or failures of one or more of the design elements. In complex systems, a single failure can cascade into a larger problem resulting in total system failure (Wasson, 2006).

In wireless systems, which are inherently flexible in nature with many simultaneous users, errors that are not detected early in the design phase can have a significant impact on the system (Viana, Maag, & Zaidi, 2011). The current testing of the SPARCCS system was performed early in the design phase so that future additions to the system would have a solid set of tests and validations on which to base new incremental designs of the system. As such, the overall final design of the SPARCCS system will be more robust with fewer errors, faults, and design flaws.

3. Test Partitioning

Systems testers must carefully decompose complex systems and fully orchestrate the testing of the units, elements and subsystems to ensure that the system is tested properly and in proper sequence so that interfaces, functions, and operational capabilities are demonstrated in a cost effective manner that leverages human and material resources and scheduling (Giadrosich, 1995). Through proper test partitioning, system integration is prevented from becoming a testing and performance bottleneck.

Through the proper test partitioning and sequencing of unit, element, and subsystem testing, the final stages of

interface, functionality and operational testing will be more viable, on schedule, and more complete; and the verification of system performance will be as accurate as possible. In addition, through proper test partitioning, tests can be grouped more accurately making testing more cost and resource effective (Wasson, 2006).

Testing a complex system such as the SPARCCS system is complex and time and resource intensive. Through proper partitioning, the complexity can be managed and time and resources can be managed effectively and a thorough testing of the system can take place to ensure proper operational functionality (Wasson, 2006).

The SPARCCS testing will have various partitions that will assist in the proper testing of the system. These partitions include various:

1. Operating systems
2. Internet browsers
3. Hand held devices
4. Communications platforms

Today’s wireless based systems are inherently and exponentially complex, especially systems that are software intensive such as the SPARCCS system. If testing is not partitioned properly, a system may not be thoroughly tested, or if it is, the testing may be cost intensive as well as time and resource intensive. Proper partitioning helps maintain control of the testing process and helps ensure thorough, complete, efficient and effective testing (Alena, et al., 2002).

4. Controlled Laboratory Testing

A controlled test laboratory (CTL) is critical to the systems engineer for the proper testing of a system. The CTL is the central entity that interconnects the elements and subsystems with the tools that will be used for testing to ensure proper conduction of the testing and to ensure that the test events are properly analyzed (Ziarco & Krzystan, 2011).

CTLs are critical as they provide a centralized location for test functions, they provide an area to stage and practice test events to ensure conformity with test requirements, and a safe and controlled environment for the tests. They ensure that tests are repeatable. They ensure that test standards are followed through calibrated and consistent test equipment. They also ensure early exposure to the elements that will be experienced in the operational environment of the system (Sprigg et al., 2011).

CTLs help complex systems to be setup as decomposed subsystems that can be tested and build back up to full system capability and tested again in that capacity. CTLs thus provide a critical area that supports testing, integration, integration testing, and qualification testing in a controlled, safe environment in a centralized location or locations (Ziarco & Krzystan, 2011).

The significance of a testing lab is clear: testing is a very complex process for many systems and managing the complex testing process in a controlled manner for baseline results is critical. CTLs help with this management. Through a centralized location, that is controlled and safe, system test engineers can conduct viable, efficient

tests that conform to testing requirements and that help simulate system environments and data in a safe and effective manner.

CTLs help manage the complexity of testing and help organize and regulate the testing environment by having all of the hardware, software, simulation tools, security, and personnel available as well as the testing tools, instruments, test benches, and unique test hardware and testing requirements located in specific physical locations. In short, CTLs help save time, money and resources and foster safety through centralized physical locations, available instruments and tools, and help provide for thorough testing through the use of the hardware/software/tools/instruments that are located at each CTL (Sprigg et al., 2011).

In the SPARCCS testing, several controlled test laboratories were set up. These SCPACCS CTLs provided controlled environments to begin the necessary basic building block testing of the system, which comprised half of the systems testing. Such CTLs provided solid Internet connections, reliable power, protection from the elements, and stable work surfaces on which to work. They also provided for stable test areas where test equipment could be positioned for longer durations than with the field tests.

In short, the SPARCCS CTLs provided consistent, stable environments for initial systems, software and hardware testing, which served as the foundation of the test program and provided baseline data used in the later, more complex field tests. The CTLs are described in detail for each

SPARCCS test event on each official test form and are summarized in the test results portion of this document.

5. Integration Testing

In the SPARCCS system integration testing is critical due to the high software and data sensitive nature of the system. In many complex system-of-systems, major problems can manifest at the interfaces of modules and systems, and therefore integration testing is critical (Sprigg et al., 2011).

The SPARCCS has two major systems that need to be integrated: the smart-phone application and the web-based application. Both are complex systems in and of themselves. Both also have a wide array of modules and systems, making the integration of them critical as well. By integrating the systems and testing those integrations rigorously through integration testing, engineers can eliminate the interface and interoperability faults and errors, and thus functional and complete systems testing will go smoother and be more reliable.

6. Interface and Functional Testing

In the SPARCCS system, interface verification should take place before functional testing. There are several reasons for this. First, in many software intensive systems, major problems can manifest at the interfaces and thus it is a logical place to begin testing. Second, it is easier to detect problems in most cases at the interface verification level. If functional testing is done first, excessive hours tracing sources of errors at the interfaces can be wasted needlessly. In short, interface verification

can save time and effort in the testing process. Interface faults can disrupt the functionality of a system (Pressman, 2010). Interface faults can include:

1. Incorrect interrupt handling
2. I/O Timing
3. Call to wrong/nonexistent procedure
4. Variable mismatch
5. Parameter mismatch
6. Incompatible data types

As can be seen in the above list, major issues can take place at the interface level. Issues like I/O timing, for example, could be very difficult to diagnose at the functional testing level, but could be more easily diagnosed at the interface level. Procedural calls, too, are more easily diagnosed at the interface level. In fact, almost all of the faults listed above would be more easily diagnosed at the interface level (Ziarco & Krzystan, 2011).

While it may take more time to get through the interface testing before getting to the functional testing, it will save time and overall effort due to the fact that interface errors are common and prevalent in software intensive systems (Kossiakoff & Sweet, 2011). By nipping them in the bud so to speak, we make our functional testing easier and more reliable.

7. Performance and Deployment Testing

The overarching goal of the SPARCCS testing is to test the system’s performance in the field. As such, intensive performance and deployment testing will be conducted in

various real life scenarios that simulate both military and police/fire/EMS situations.

Performance testing addresses the run time performance of a system within the context of a systems integrated platform. This type of testing occurs in all phases of the systems testing process and requires both hardware and software instrumentation for full effectiveness (Pressman, 2010). In SPARCCS testing, performance testing will be at the forefront of all test scenarios, as the main goal of the current SPARCCS testing is to test the system in its current state of development to facilitate improved performance for the later stages of design.

Deployment testing, also known as configuration testing, is structured to test the system in the environment in which it is designed to operate. Deployment testing tests the following (Pressman, 2010):

1. Installation procedures
2. Installation methodologies
3. Installation configurations
4. Operating systems platform conformance
5. Internet browser platform conformance
6. Hardware platform conformance

In essence, deployment testing tests the actual customer environment in which the system will operate including the customer’s installation of the system, the customer’s configuration of the system, and all other issues related to the actual real world use of the system.

Deployment testing also covers the actual environments in which the system will be used including the physical

environments, the environmental settings, the potential users and their skill levels, as well as other extraneous factors (Pressman, 2010).

The SPARCCS system testing will attempt to emulate the various real world uses of the system including installation, configuration, and deployment of the system. This testing will encompass both the hardware and software dimensions of the system as well as the specialized nature of wireless networking systems. In short, the SPARCCS testing will be extensive and will begin with simple installation tests and end with complex real world scenario testing.

C. SOFTWARE TESTING

Software testing is the dynamic verification of program behavior on a finite set of test cases that are carefully and suitably selected from what is usually an infinite domain and are run against the expected behavior of the system (Bertolino, 2001). Software testing should be geared towards problem prevention, and all quality testing should point to the avoidance of problems in the final system (IEEE SWEBOK, 2004). Software testing is a mandatory part of testing and system development, as it evaluates the quality of the software product in the system by identifying performance defects and problems and directly helps improve the system (Bertolino, 2001).

Most wireless ad-hoc systems today are software intensive (Viana, Maag, & Zaidi, 2011). The SPARCCS system is no exception. Small software errors can cascade into major errors or faults that can have catastrophic consequences (Jorgensen, 2002).

D. HARDWARE TESTING

The hardware in the SPARCCS system is critical to the system success. In the system, several pieces of hardware are utilized:

1. Laptop computers
2. Smart phones
3. Handheld tablet PCs (7” and 10”)
4. Various Antennae
5. WIFI Jet Pack
6. Satellite communication systems (BGAN)
7. Wave Relay and WIMAX devices

Each piece of hardware must thus be partitioned and tested before being integrated into the system for systems testing (Wasson, 2006, & Alena, et al., 2002). Hardware tests will include basic functionality, internal systems functionality, and designed functionality and communications capability in the wireless spectrum.

All SPARCCS hardware platforms will be tested in the beginning of the test sequences to ensure that the SPARCCS software functionality is its inherent functionality and not a result of hardware issues. Proper documentation of the hardware testing will be conducted to ensure proper reference during the overall systems testing. Hardware

testing will be initially conducted in the indoor and outdoor laboratories, which are described later in this document.

Additionally, the SPARCCS hardware will be tested in various combinations to ensure that there are no compatibility issues between the hardware platforms. This testing will begin with basic configurations and advance to more complex configurations to ensure full systems compatibility among the various hardware devices.

E. WHEN TO STOP TESTING

The process of testing in a system can be literally endless. The test program cannot be continued until all of the faults, errors and defects are found, as this is economically impossible and infeasible in terms of time, money, and resources. As such, the scope and limits of the testing must be firmly established. Testing is, in essence, a tradeoff between time, budget, and system quality (Pan, 2012).

The SPARCCS testing will encompass a selected set of test scenarios and a limited number of hardware platforms. In addition, the wireless communications technologies will be limited to those that would realistically be feasible in the real operational environment.

Overall, the goal of SPARCCS testing is to encompass enough test scenarios to establish a solid demonstration of the system performance at its current state of development. While limited in scope, the testing will provide guidance to the current SPARCCS developers and will help them avoid negative issues as the development continues.

F. CHAPTER SUMMARY

The testing plan for any system is critical for the long-term success of the project. The earlier a problem is detected in the system's development the less expensive it is to fix and the less time the system will be in the repair stage for that issue (Giadrosich, 1995, Sprigg et al., 2011, & Biemer, 2010).

The systems engineering test methodology was chosen for the SPARCCS system since SPARRCS is a complex system with hardware components, software components, communication protocols and methodologies and several systems interfaces. Through thorough and progressive systems testing, which is partitioned properly and constructed properly, the SPARCCS system will have a solid testing foundation to assist in the elimination of systems errors, faults, design flaws and other technical issues, facilitating a more expeditious and technically-sound development of the system in its later stages.

The next chapter will discuss the requirements of the system as they relate to the testing of the system. The test requirements will be developed and matched to specific testing levels. The phases of testing will be discussed as will the qualification and audit plans for SPARCCS testing. These plans will help with the quality assurance of the testing and adherence to proper testing procedures.

III. SPARCCS TECHNOLOGY INTEGRATED TEST PLAN

This chapter develops an integrated test plan for SPARCCS. It begins with a thorough requirements analysis for the specific scope of the system that will be tested in this thesis. The requirements are placed in a Verification Cross Reference Matrix (VCRM), which is a requirements engineering tool for managing system requirements. The test plan approach is then developed to demonstrate the comprehensive performance testing approach, the levels of testing and the various test environments. The chapter concludes with the qualification and audit plans to ensure that the test plan and sequences are accurate and appropriate for the levels and scope of the required SPARCCS testing.

A. INTRODUCTION

The customers of SPARCCS are military, police, fire, and EMS at the local, regional and federal levels. As such, a set of requirements must be derived from the projected use of the system. A CONOPS (Concept of Operations) for SPARCCS has been developed as presented in Appendix A.

Our test plan initiates from an analysis of the system requirements. The following section will develop the SPARCCS requirements that will serve as the foundation for the test events in the SPARCCS testing plan.

B. TEST REQUIREMENTS ANALYSIS

1. Requirements Analysis Description

In the SPARCCS system, there are 57 individual test requirements statements derived for the system. These

requirements were derived from one of three dimensions of the system: the entire SPARCCS system, the smart phone application, and the web application.

Each requirement was analyzed, evaluated and placed into the VCRM in either an unchanged state or in a modified or split state, depending on the level of precision needed for each particular requirement, as derived from the current system documentation. Careful consideration was given to the clarity, specificity, and testability of each requirement placed in the VCRM to ensure precision in the test cases derived from each specific requirement.

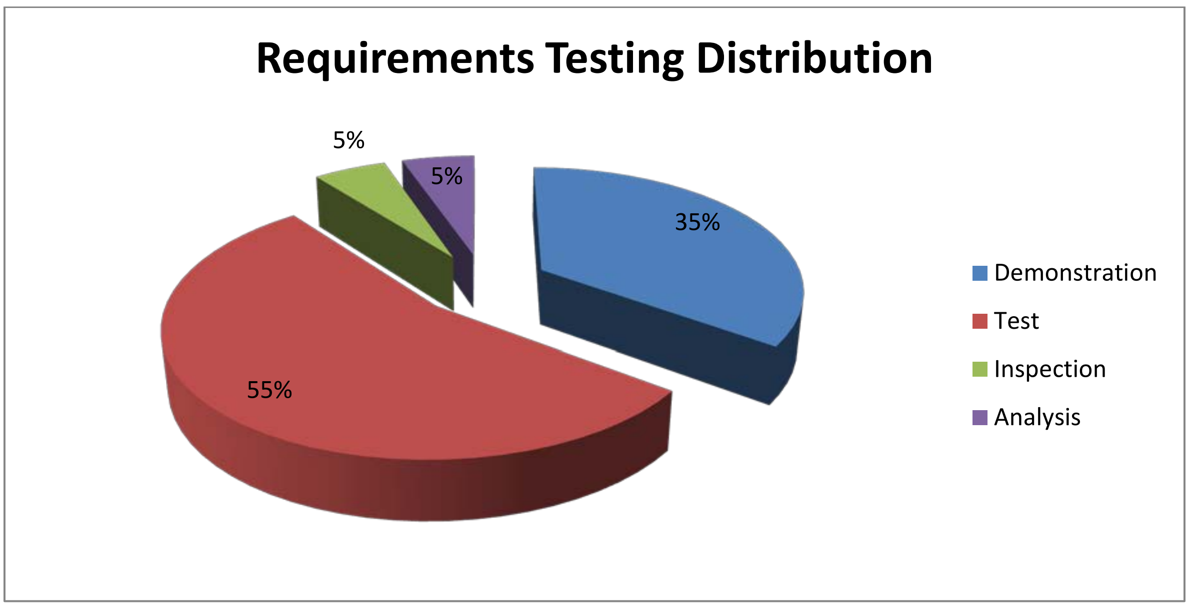

Figure 4. Requirements Test Distribution

2. VCRM Matrix

Our VCRM as shown in Table 1 contains 57 overall system test requirements that were derived to serve as the foundation of the SPARCCS testing program. The matrix consists of a unique requirements identification number for each test item, a description of the actual requirement, the method of testing, and the level of testing. The methods of testing a system are: demonstration (D), test (T), inspection (I), and analysis (A). The levels of testing are: hardware, software, and systems

Table 1. SPARCCS VCRM Matrix

Req ID	Requirement	Method	Level
001	The SPARCCS system shall operate on Android smart phone hardware.	D	Hardware
002	The SPARCCS system shall operate on Android tablet PCs of various sizes.	D	Hardware
003	The SPARCCS system shall operate on the Android operating system of version 2.2 or greater.	T	Software
004	The SPARCCS command system shall operate on any modern web browser.	D	Software
005	The SPARCCS system shall operate on the Google cloud application platform (Google App Engine).	T	Systems
006	The SPARCCS system shall operate on and fully leverage the Google Datastore platform.	T	Software
007	The SPARCCS system shall operate on[G1] the Android SQLite database platform.	T	Software
008	The SPARCCS system shall operate under HTTPPosts and HTTPRequests using HTTP servlets for Android to server communications.	T	Software

Req ID	Requirement	Method	Level
009	The SPARCCS system shall operate under Remote Procedure Calls for web client to server communications.	T	Software
010	The SPARCCS system shall utilize a user login system.	I	Software
011	The SPARCCS system shall utilize the commercially available GPS system present on the user device.	I	System
012	The SPARCCS system shall utilize Google Maps as the visual map interface.	I	Software
013	The user login system shall enable user accounts to be created on the Android application or on the command program.	D	Software
014	The user login system shall acquire user first name, middle initial, and last name; email address, phone number, unit, and password.	D	Software
015	The user login system shall present 5 types for user login registration: military, fire, medical, humanitarian assistance, or law enforcement.	D	Software
016	The user login system shall create a username with a unique and meaningful user ID.	D	Software
017	The user interface shall allow a user to create a mission.	D	Software
018	The user interface shall allow a user to join a mission.	T	Software
019	The user interface shall allow a user to edit a mission.	T	Software
020	The user interface shall allow a user to view a mission.	D	Software
021	The user interface shall allow a user to create a point of interest.	T	Software
022	The user interface shall allow a user to join a point of interest.	T	Software

Req ID	Requirement	Method	Level
023	The user interface shall allow a user to edit a point of interest.	T	Software
024	The user interface shall allow a user to view a point of interest.	D	Software
025	The application shall have the ability to capture images and place them into the system.	T	System
026	The application shall have the ability to edit images from a mission.	T	Software
027	The application shall have the ability to view images from a mission.	T	Software
028	The application shall have the ability to delete images from a mission.	T	Software
029	The application shall have the ability to view all missions on a Google map.	T	Software
030	The application shall have the ability to view all points of interest on a Google map.	T	Software
031	The application shall have the ability to view all images on a Google map.	T	Software
032	The application shall have the ability to view all missions in a list format.	T	Software
033	The application shall have the ability to view all points of interest in a list format.	T	Software
034	The application shall have the ability to view all images in a list format.	T	Software
035	The application shall have the ability to view all responders in a list format.	T	Software
036	The application shall have the ability to retrieve GPS location from the host hardware.	T	Systems
037	The application shall have the ability to correlate GPS location with missions, points of interest, and images.	T	Systems
038	The application shall have the ability to store mission, image, and point of interest data on the SQLite database.	T	Systems

Req ID	Requirement	Method	Level
039	The application shall have the ability to store mission, image, and point of interest data on the Google Datastore database.	T	Systems
040	The application shall have the ability to sync data between the SQLite database and the Google Datastore database.	T	Systems
041	The application shall collect information concerning the mission including userID, mission name, mission description, mission leader, mission creator, and mission information.	D	Software
042	The application shall collect information on a point of interest including userID, description, time, creator, correlating mission, location notes, and latitude and longitude.	D	Software
043	The application shall place a gold flag on the Google map of the point of interest's creator at the location of creation within 2 meters.	D	Software
044	The application shall place a gold flag on the Google map of the point of interest of all members of the mission.	D	Systems
045	The application shall collect information on an image including userID, description, time, creator, correlating mission, location notes, and latitude and longitude.	D	Software
046	The application shall place a camera icon on the Google map of the image creator at the location of creation within 2 meters.	D	Software
047	The application shall place a camera icon on the Google map at the location of the photograph.	D	Systems
048	The headquarters application shall have a list menu listing all missions, points of interest, responders, photos, map options, and a live Google map of the mission area.	D	Software

Req ID	Requirement	Method	Level
049	The headquarters application shall have the ability to click on an icon on the Google Map and have the mission details listed.	D	Software
050	The headquarters application shall have the ability to display accurate mission statistics in real time.	A	Software
051	The headquarters application shall have the ability to display accurate point of interest statistics in real time.	A	Software
052	The headquarters application shall have the ability to display accurate responder statistics in real time.	A	Software
053	The headquarters application shall have the ability to display accurate photos on the photo panel in real time.	D	Software
054	The SPARCCS system shall operate on a commercial WIFI network.	T	Systems
055	The SPARCCS system shall operate on a BGAN satellite network.	T	Systems
056	The SPARCCS system shall operate on a hybrid BGAN/Wave Relay network.	T	Systems
067	The SPARCCS system shall operate on a hybrid BGAN/WIMAX network.	T	Systems

C. TEST APPROACH, FLOW, AND SEQUENCE

1. Overall Approach

Live systems testing will be the primary quantitative method of research used in this study. All data will be extracted from live test cases and all data will be original to this research. Proper statistical and quantitative analysis will be conducted on the data to formulate conclusions about the system. While qualitative

methods will be used in some tests, their results will be quantized and analyzed as quantitative data.

The test approach will involve four discrete areas:

1. The development of test requirements
2. The three-phase test plan
3. The qualification plan
4. The audit plan

The SPARCCS test approach will fulfill these areas sequentially to ensure complete testing, review and auditing. The sequential nature of the test approach will ensure that all test items are carefully set up with pre-conditions and carefully reviewed and audited to ensure the clarity, accuracy, precision, and complete fulfillment of the SPARCCS test requirements.

The testing plan has several overall divisions. First, a comprehensive set of test requirements will be developed to ensure the formality of the testing program and to ensure the comprehensive nature and strict organization of the test program. Prerequisite requirements conditions will be analyzed and set up to ensure that all of the conditions are in place before testing will begin. The test engineer will ensure and verify that these conditions are fulfilled before the commencement of formal testing.

Second, the testing will begin. The SPARCCS tests are categorized into three phases with gradual progression of difficulty and architectural system involvement. Through the systematic testing of the four phases, a complete set of tests will be performed covering start up, system operations, system performance, and abnormal conditions.

Third, a comprehensive field-testing program will be established and conducted in a live scenario to ensure the real world operability of the SPARCCS system.

Finally, once SPARCCS testing is complete, the review and audit plan will be conducted to review the issues, modifications, and agreement regarding each test item. Audits are conducted for each test to ensure that the procedures are followed correctly and test results are valid and accurate.

2. Phases of Testing

SPARCCS tests will be categorized into three phases with gradual progression of difficulty and system involvement. These phases are depicted in Table 2.

Table 2. Phases of SPARCCS Testing

Phase	**Description**
1	Perform start-up testing: The purpose of this test phase is to assess the initial system capability of start-up, log-in, and initialization.
2	Perform operation related testing: The purpose of this test phase is to assess system performance under normal operation. The tests will be conducted in the test labs, both indoor and outdoor, under controlled conditions.
3	Field tests: the system will be subjected to live field-testing in full operating conditions by a team of testers.

The field tests will be conducted in the tactical areas of the former Ft. Ord, a decommissioned US Army installation that was the home to a full infantry division. The remote areas of Ft. Ord provide tactical simulation environment similar to what actual users of the SPARCCS system will experience. The region has a plethora of terrains, such as heavily wooded areas, flatlands, fields, extreme hills and valleys, as well as mixed terrains.

D. QUALIFICATION PLAN FOR ACCURATE TESTING

The development of a testing plan must include qualification conditions that ensure the accuracy and integrity of the tests and the overall plan (Ziarco & Krzystan, 2011, Sprigg et al., 2011). Table 3 details the qualification conditions of the SPARCCS testing that ensure proper and accurate testing of the system. The conditions will be reviewed for each test event and an analysis and reconciliation of the conditions will occur with each test event and will be documented with the event.

Table 3. SPARCCS Test Qualification Conditions

Condition	**Description**
1	Before tests commence for the SPARCCS system, there needs to be assurance that the system has been completely built up to the required platform architecture for testing and integrated and that development for the current build has concluded. Existing issues and outstanding concerns from the development phase needs to be

Condition	Description
	resolved before testing can begin.
2	The SPARCCS software and system components such as phones, laptops, servers, routers, etc. are under formal configuration management to ensure that changes during the testing phase will be truthfully reflected and recorded. During actual testing, target hardware and software that reflect actual operation are used and need to be ready before testing.
3	In order to have test integrity, test planning must be conducted in the form of a meeting to brief SPARCCS test members and discuss testing detail. Some tasks under test planning include actions to refine developed test procedures and confirm the tools and resources needed for qualification-testing are ready for use.
4	To ensure the quality of individual SPARCCS tests, there must be multiple testing dry runs to refine test procedures, correct existing issues, and confirm system performance.
5	Performance of test readiness review must be used to determine system readiness, evaluate results of earlier dry runs, define roles and responsibilities of test

Condition	Description
	team, report validation of test tools, provide test schedule, define retest criteria, and define success criteria.

E. CONTROLLED TEST CASES

The purpose of controlled test cases is to test the SPARCCS system in a structured environment with limited variables and set conditions to gain an initial baseline for the system without undue influences from extraneous external variables (Giadrosich, 1995; Ziarco, & Krzystan, 2011). An initial controlled environment is critical for the SPARCCS system to ensure that it has basic functionality, that the interfaces are functional, and that the overall system is functioning as designed.

Since this research is the initial set of tests for the SPARCCS system, an extensive set of controlled tests is vital to ensure proper continued development of the software and to ensure that the field tests are conducted with a solid system foundational base.

The controlled tests of the SPARCCS system shall be conducted in two basic environments, an indoor lab environment and a limited, confined outdoor environment. These environments will be the same throughout controlled testing to ensure consistency and to ensure the development of accurate and systematic system baselines.

F. FIELD TEST PLAN

1. Purpose

Field-testing (also known as live environmental testing) assures that the system will perform in its expected environments as required, when required, and as long as required. A system can be tested to ensure that it meets specifications, but if the system does not operate well in its target environment, the fact that it meets specifications may be a moot point.

SPARCCS’ field-testing will be conducted at the former Ft. Ord to ensure that the SPARCCS system performs well in the actual operational environment. Tests will cover all areas not fully tested in the wireless lab and controlled test areas. The SPARCCS field tests will be designed to improve system confidence and to thoroughly cover issues that may arise in the real world. The tests will also be designed to uncover areas that may have been missed in lab and controlled testing.

2. Field Test Descriptions

The test descriptions for the field tests are contained in Table 4. Each test will have its own set of test sheets for formal test documentation while the test is being conducted. Each test will have a specific test location listed in the table, with further description of the location following the table. The table will list the specific requirement or requirements with which the test corresponds.

As with the controlled testing scenarios, all test cases must correspond with at least one test requirement for proper systems testing (Sprigg, Krzystan, & Ziarco,

2010). Additionally, the level of confidence will be annotated on the table for each test case.

Table 4. Field Test Descriptions

Test Number	**Test Location**	**Test Description**	**Limitations/ Constraints**
FT1	Camp Roberts	General system testing in the field, multiple user testing, live system tracking testing, WIFI testing, Mission creation and POI creation, photograph and mission note creation, extended use testing.	Limited on ability to maneuver vehicle on Army range. Limited number of users. Time limitation to daylight hours. Possible limitation on wireless service based on location of testing in relation to nearest service tower.
FT2	Camp Roberts	Extensive testing of Wave Relay and WIMAX systems over 8 miles of terrain, compare and contrast Wave Relay and WIMAX performance, BGAN Internet connectivity, SPARCCS system usage over WIMAX and Wave Relay with BGAN connectivity. Mission	Time limitation to daylight hours. Stationary positioning of wireless devices. Limitations on device positioning due to power requirements (120 v) of Wave Relay and WIMAX devices,

Test Number	Test Location	Test Description	Limitations/ Constraints
		creation, POI creation, precision tracking, photographic capabilities, mission note capabilities, overall SPARCCS functionality.	requires power source and elevated location as well as line of sight requirement for WIMAX network.
FT3	MIRA Marina Campus	Extensive testing of SPARCCS in a multi-building campus type setting. Buildings of multiple types of construction and dimensions/layouts. WIFI and BGAN testing. Mission creation, POI creation, photographic capabilities, mission note capabilities, GPS positioning overall SPARCCS functionality.	Possible limitation on WIFI connectivity due to proximity to tower.
FT4	MIRA Chews Ridge Location	High altitude, remote setting wilderness testing. BGAN testing. GPS, Mission creation, POI creation, photographic capabilities, mission	BGAN testing only, no WIFI signal available. Difficult location to travel to. Remote setting.

Test Number	Test Location	Test Description	Limitations/ Constraints
		note capabilities, GPS positioning overall SPARCCS functionality.	
FT5	Former Ft Ord Concrete Test Range	Precision testing on WIFI, and BGAN on level, concrete test range. Distance signal testing. SPARCCS system testing and functionality testing.	Possible limitation on WIFI connectivity due to proximity to tower.
FT6	Former Ft Ord Wildland Testing	Testing SPARCCS with WIFI and BGAN connectivity in various states of wildland configuration: low shrubs to thick woods. SPARCCS system testing and functionality testing.	Possible limitation on WIFI connectivity due to proximity to tower. Possible issues with line of sight BGAN issues with satellite due to woods.
FT7	Monterey County, CA Highways	Precision tracking using WIFI. Travel 100 miles in one direction with various stops. Mission creation, POI creation, GPS positioning precision, movement tracking, mission notes,	Possible breaks in WIFI connectivity due to location of traveling vehicle.

Test Number	Test Location	Test Description	Limitations/ Constraints
		photographic imaging, multi user tracking.	

G. TEST EQUIPMENT

The testing of systems software requires various pieces of test equipment, and the SPARCCS testing is no different. The equipment can be broken down into three categories: test support equipment, test platforms, and wireless technologies. The following sections briefly describe the equipment.

1. Test Support Equipment

The test support equipment used in the SPARCCS testing was vital for system positioning and system safety. Figure 5 depicts the test support equipment used in the SPARCCS testing.

Figure 5. Test Support Equipment

Equipment includes two equipment stands with ridges for laptop and communication device support, a rubber mat for device support and high visibility cones for safety purposes. A precision land-measuring wheel is included in the equipment for measurement of land to the nearest foot. A compass is included to assist in the pointing of the BGAN, Wave Relay, and WIMAX devices.

2. Wireless Technology Equipment

Wireless technology is at the heart of the SPARCCS testing. The technologies that will be tested are the BGAN system, Figure 6, the Verizon WIFI 4G LTE Jet Pack, Figure 7, the Wave Relay System, Figure 8, and the WIMAX system, Figure 9. The equipment will be described in detail in the testing section as well as in the appendices.

Figure 6. Hughes 9202 Inmarsat BGAN System

Figure 7. Verizon 4G LTE Jetpack

Figure 8. Persistent Systems Wave Relay Radio

Figure 9. Redline Communications WIMAX System

3. Wireless Test Devices

The SPARCCS system is designed to work on Android devices. As such, various Android devices are used in the tests of this research. Table 5 lists the devices used in the testing of the SPARCCS system.

Table 5. Test Devices

Device Type	Make	Model	Android Version
Smartphone	HTC	EVO	2.2
Smartphone	Motorola	Droid X	2.3.4
Smartphone	LG	Enlighten	2.3
Tablet (7”)	Samsung	Galaxy	4.0.3
Tablet (7”)	Asus	A100	3.2.1
Tablet (10”)	Toshiba	AT300	4.0.3

H. CHAPTER SUMMARY

The proper setup of a testing plan is critical for the overall success of the testing. This chapter developed the system requirements to facilitate the accurate development of the test cases ensuring that the tests are completed correctly and ensuring that the correct tests are completed. The qualification plan was developed to ensure that the system is tested with a high level of quality assurance. The controlled test plans and field test plans were developed to demonstrate the depth of the testing program. Finally, the equipment used in the testing was introduced.

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IV. TEST RESULTS

This chapter covers all of the SPARCCS tests in detail. It begins with the controlled tests and the results of those tests, followed by the field tests. An emphasis on graphics and images can be found in this chapter to demonstrate the specific test environments, test conditions, and test results.

A. CONTROLLED TESTING

Controlled testing occurred in several locations. Indoor testing was conducted in an indoor residential testing laboratory. Outdoor controlled testing occurred at several locations including a small wooded area, the campus of the California Department of Forestry and Fire Protection in Monterey, California, and at the Naval Postgraduate School. Appendix A contains the field notes from the controlled testing.

1. Handheld Device Testing

The wireless devices used in the field-testing were tested rigorously over the course of several weeks to ensure their viability. As new devices were acquired, they were put through the same set of tests to ensure field test consistency and accuracy. Table 6 describes the handheld test details.

Table 6. Handheld Test Details

Test Dates	May 3–26, 2012, June 11-18, 2012
Test Personnel	Donna Dulo
Equipment	All listed handheld devices of Table 5, Verizon Jetpack with Antenna
Test Software	GPS-Test, SpeedTest
Test Locations	Indoor Test Lab in Seaside, CA
Test Objectives	To determine the viability of the handheld devices to be used in the field tests.

The handheld testing was comprised of several components. The first was GPS testing through a program called GPS-Test that tested the functionality of GPS on the device. The second test was a basic wireless connectivity test where each device was connected to the Verizon Jetpack network to test its functionality on a network. The SpeedTest software, Figure 10, was used to see that data was being uploaded and downloaded to the device. The SpeedTest software was configured in “high test” effectiveness mode, as it was in all tests in this research to ensure test accuracy. This mode decreased the graphics of the software in lieu of more accurate data flow readings.

The third test was to test the ability of SPARCCS to be loaded properly on the device. This test loaded SPARCCS from the Gmail system directly on each device. The final test was the operating system test, which tested the ability of SPARCCS to open as an application on the device’s specific operating system.

Figure 10. Speed Test Testing Software

The results of the testing are found in Table 7. Note the specific operating system issue with the HTC smart phone device that contained the Android Operating System (OS) version 2.2.

Table 7. Results of Device Basic Functionality Testing

Device	**OS**	**GPS Test**	**Wireless Connectivity Test**	**SPARCCS Application Install Test**	**SPARCCS Basic Operation Test**
HTC EVO	2.2	Passed	Passed	Passed	Failed
Droid X	2.3.4	Passed	Passed	Passed	Passed
Enlighten	2.3	Passed	Passed	Passed	Passed
Galaxy	4.0.3	Passed	Passed	Passed	Passed
A100	3.2.1	Passed	Passed	Passed	Passed
AT300	4.0.3	Passed	Passed	Passed	Passed

The HTC smart phone was not able to run the SPARCCS application so further testing into this issue was warranted. A second phone of equal make, model, and OS was tested and again the SPARCCS application did not function. As such, a second type of device was acquired, a Lenovo tablet PC with the Android OS version 2.2 was tested and SPARCCS was loaded. On this device, again, the application did not run. Thus it was demonstrated that while the Google Android Application Programming Interface (API) used to develop SPARCCS was designed to develop applications that run on Android 2.2 or greater, this was not the case with the SPARCCS application. Based on the controlled testing it can be concluded that SPARCCS must be loaded on a device that supports the Android OS version 2.3 through the latest version 4.0.3.

2. Wireless Technology Testing

The wireless technology testing program was developed to test the specific wireless devices to be used in the SPARCCS field testing. This testing was designed to ensure that the equipment worked properly so that any anomalies or issues identified could be attributable to the SPARCCS application or the limitations of the wireless devices. Table 8 describes the testing of the wireless devices.

Table 8. Wireless Device Test Details

Test Dates	June 8, June 14, June 21, June 23-27 2012
Test Personnel	Donna Dulo, NPS Hastily Formed Network Group Personnel (HFN) and California Department of Forestry and Fire Protection Personnel
Equipment	Hughes 9202 BGAN, Persistent Systems Wave Relay Radios, WiMax bridges, Verizon Jetpack with Antenna
Test Software	SpeedTest
Test Locations	Outdoor Test Lab in Seaside, CA, Naval Postgraduate School Campus (NPS), CalFire Campus.
Test Objectives	To determine the viability of the wireless devices to be used in the field tests.

The details of the individual tests are presented in Section A of Appendix A. The table presents the specific qualitative data of each of the device tests. Note the

specific requirements for line of sight in some of the devices. Figure 11 represents one of the impediments to the BGAN as noted in the test results.

Figure 11. Complete Impediment to BGAN Signal

The device testing at the outdoor testing range (Figure 12) demonstrated the viability and functionality of the devices. It also pointed out the criticality of a full satellite line of sight for the BGAN device, which includes a clear and unobstructed skyline. The use of an external compass aided in the more rapid and accurate pointing of the device, which helped increase the data rate into the WIFI cloud. The testing clearly indicated that simple issues such as a window screen, a fence wire, a tree branch, and a partial view of the satellite could cause the BGAN signal to degrade or drop.

Figure 12. Outdoor Testing Range

The testing also indicated a clear need for precise line of sight between the WiMax devices. Even a slight deviation from line of sight rendered the signal weak or lost. The wave relay radios did not require line of sight and worked well at any angle with the omni-directional antenna attached to the radios. The need for a tethered power supply complicated the use of both types of devices. The mobility of the devices was strictly limited to the length of the power extension cords and the availability of power outlets. The use of a car lighter power inverter was used successfully; however, the placement of the vehicle in the wireless mesh limited the pointing of both devices and also caused clutter in the network range. This power situation will affect the use of these devices in SPARCCS applications that require mobility.

Figure 13. Testing the BGAN at the Outdoor Testing Range

Finally, the outdoor tests demonstrated that the Jetpack and BGAN devices worked well in the outdoor environment with an Android device. Note the use of the external compass in Figure 13. Through the use of the SpeedTest software, data flows were demonstrated to show the proper functionality of the devices at a range of 200 feet.

All four devices were shown to be viable and functional and ready for the field tests with the SPARCCS applications. The limitations of the devices, as discovered during these tests, facilitated more accurate field test setups.

3. Initial Application Testing

The testing of the Android devices and the wireless devices provided a solid basis for the testing of the

application in the indoor test laboratory. Through properly functioning devices, the application was tested in an isolated manner so that issues could be spotted and attributed to the application and not the hardware. The application was tested exclusively on the Jetpack to keep consistency with all of the tests. The signal strength was at a consistent “four bars” and the same physical location was used for the tests.

Table 9. Application Tests

Test Dates	May 15 – June 2, 2012
Test Personnel	Donna Dulo
Equipment	All listed handheld devices of Table 5, Verizon Jetpack with Antenna, Toshiba laptop, Apple iPad 1.
Test Software	SPARCCS Application
Test Locations	Indoor Test Lab in Seaside, CA
Test Objectives	To determine the initial viability of SPARCCS application to be used in the field tests.

The application testing (Table 9) tested the basics of SPARCCS. More complete functionality was tested in the field tests. As a result, the scope of the initial application tests was limited to basicfunctionality. The handheld device and the Internet application were both tested.

A specific testing paradigm must be noted. The SPARCCS system was tested as a complete system. Thus, when a

function of the mobile application was tested, the function was followed through from start to finish, and all impacts of the function were evaluated. If a function produced changes or results on the SPARCCS Internet application, then the testing followed the function from its start on the mobile application through the final results on the Internet application. This allowed SPARCCS to be tested in as complete a manner as possible, to assist in uncovering any issues with functions and processes as they impacted the entire SPARCCS package.

The testing of the application went well over the course of the several months. Various issues were noted in the tests and are indicated below. Complete qualitative field notes can be found in Section A of Appendix A.

Testing began with account creation. This process worked well on both the Internet application and the mobile application. The acronym DORCCS, which was the name of an earlier version of this application kept popping up in message screens, as shown in Figure 14. The code should be reviewed to eliminate this as it may confuse potential users of the system. A second issue with account creation was a human factors issue with the smart phones. It was extremely difficult to create accounts on these devices as the screens are small, and the screen-based keypads make the screen even smaller. This led to continual errors in data input and the need to restart the account creation process. This issue could be rectified with input screens more tailored to the human hand. Otherwise, on the tablets and on the Internet application, account creation worked well and the accounts appeared within minutes on the

Internet application when created on mobile devices and instantly when created on the Internet application.

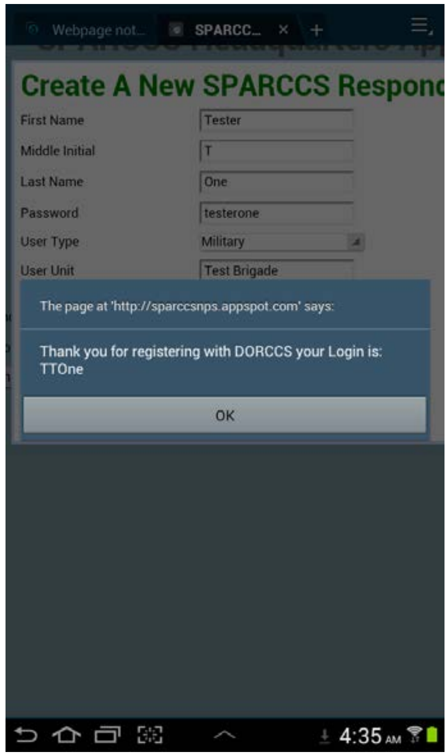

Figure 14. Example of Acronym Mismatch

The mobile and Internet applications went through extensive login testing, which was a basic test to see if accounts created were viable and facilitated login into the system. All devices and laptops were able to login to the system on both applications without incident. An issue did arise during testing that must be mentioned. At a low signal, the SPARCCS mobile login screen was not painted properly on the screen. This issue arose several times during testing. This was tested thoroughly and it appears that at 0-1 “bars,” this issue occurs, Figure 15, reader’s left image. With 1-5 “bars” this does not arise, Figure 16

reader's right image. Through rigorous testing of this issue it was confirmed that this is a signal strength issue only, not a SPARCCS application issue. This should be noted in SPARCCS troubleshooting documentation.

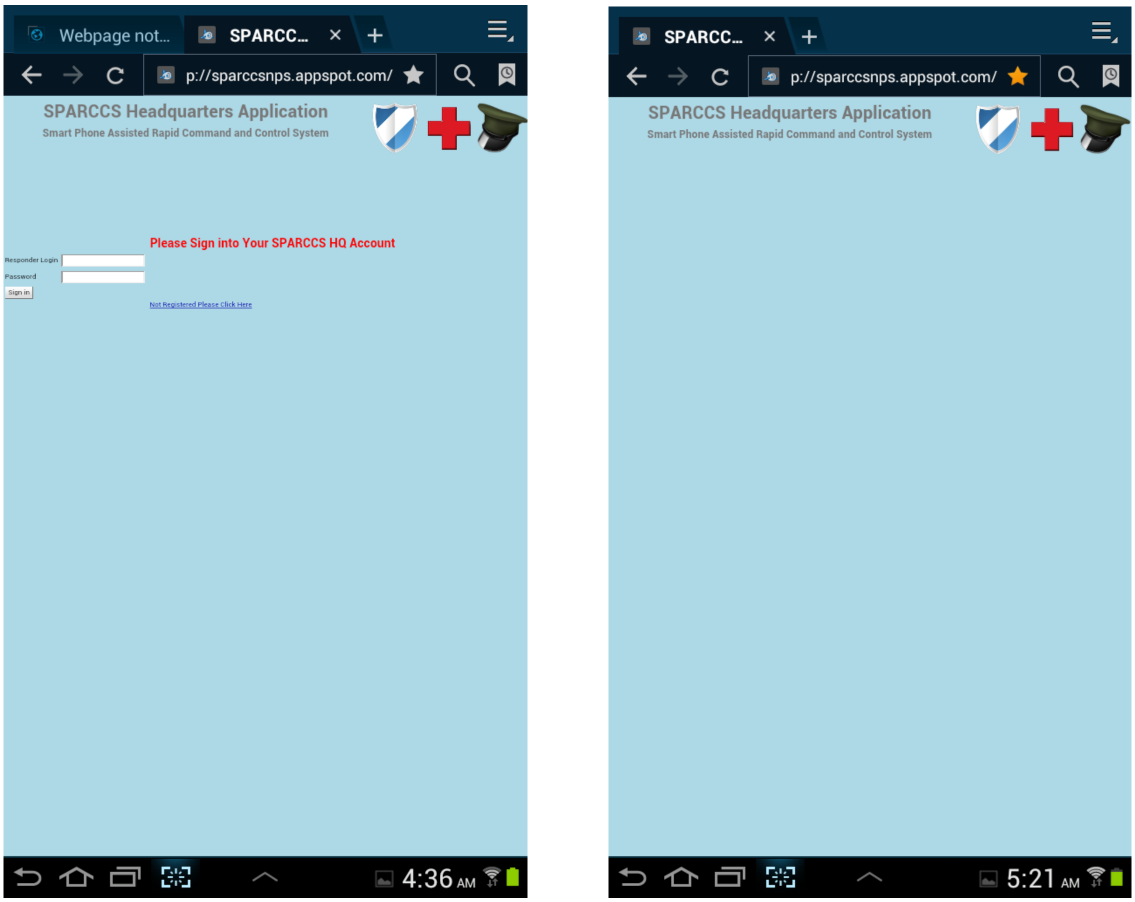

Figure 15. Demonstration of Proper and Incomplete Login Screen Presentation

The mission creation and join function was tested on both applications. The mission creation function worked successfully on both applications in most instances. However, in some cases it was difficult to navigate from the user screen to the mission creation screen and back again. For example, when a mission was created or joined,

the back navigation brought the user back to the mission creation/join screen and the only option was to go back into the mission creation page. To solve this issue the application had to be restarted. This occurred usually when a new mission was created and then a user tried to join the mission shortly after. This appears to be a synchronization issue between the device creating the new mission and the shared database. There were no issues on the Internet application.

A critical part of the SPARCCS application is the Point of Interest (POI) function. The POI function was tested on all devices with many instances on each device. This function worked well on all devices without incident. The POIs created appeared on the Internet application as input and the Google map was updated with the POI symbol at the relative point of the POI. More in depth testing of the POI function was conducted in the field tests and will appear later in this chapter.

A central function of the SPARCCS application is the photographic capability, as it captures critical images of the mission to send back to command and control for enhanced situational awareness. The photographic function was tested on all devices. In each instance a photograph was taken and input to the system. In all cases the photograph was successfully transferred and visible in the Internet application. The photographs were clear and of high quality. The camera icon also appeared on the Google map at the point of the image acquisition. No issues were discovered after extensive testing of this function. More in depth testing of the photographic function was conducted in the field tests and will appear later in this chapter.

The GPS integration capability of SPARCCS is a central feature of the application and its proper functionality is central to the purpose of the SPARCCS application. All devices were tested with their GPS capabilities in relation to the SPARCCS application. All instances with the Google maps presented precise maps with the current user icon of SPARCCS located within 5 feet of the actual location of the device. In all cases, the Google map was refreshed properly when the user moved location with the device. No issues were uncovered concerning Google maps or GPS issues. During multiple logins of users, the current user was seen as an Android icon while all of the others were seen as green stars, Figure 16.

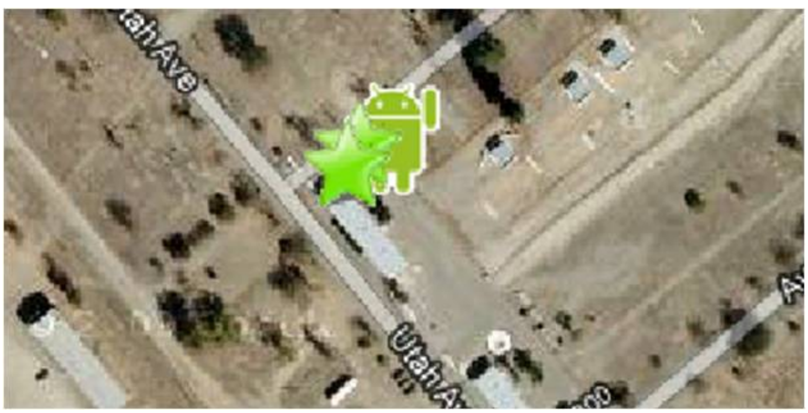

Figure 16. User Icon and Team Member Icons

While the icons demonstrated accurate positioning, it was impossible to tell which user was associated with a given star icon. Thus, the screen had several star icons on the map, but individual users could not be distinguished, which may be a critical issue in the real world where team leaders and members as well as command and control personnel need to know exactly “who is where” during the

mission. This issue should be improved in future versions of the software with different icons representing different users.

Finally, the SPARCCS Internet application did not work on the U.S. Army network. The “us.army.mil” domain specifically blocks all Google Appspot applications. This restriction suggests consideration of porting the application away from the Google cloud should it ever be considered for application to U.S. Army networks.

Thus, after extensive basic testing of the SPARCCS application, the application was ready for more in depth field-testing. It must be noted that the above tests were for basic functionality. More in depth testing was reserved for the field tests that follow in the next section. In the spirit of the conservation of space, advanced features issues that were noted in the basic application testing are brought up in the field-testing as to avoid repetition of information. The following section describes the field tests in depth.

B. FIELD TESTING

The field-testing program was conducted to demonstrate and test the SPARCCS application in real world settings. The field tests occurred over the course of three months. All attempts were made to keep the scenarios real and applicable to potential police, fire, and military settings. Each field test scenario was treated as a discrete entity, no previous data or test information was used to ensure that sterile tests were facilitated.

1. Camp Roberts Field Test I

The initial Camp Roberts field test program tested the SPARCCS application in the context of a real world Army scenario. Its main goals were to test the application in an Army field setting in the test range of Camp Roberts, California, a California National Guard installation that specializes in the training of National Guardsmen. Table 10 describes the tests.

Table 10. Test Details of the Camp Roberts Initial Testing

Test Dates	July 12, 2012
Test Personnel	Donna Dulo, John Gibson (driver)
Equipment	All listed handheld devices of Table 5, Verizon Jetpack with Antenna and car power cord. Pickup truck.
Test Software	SPARCCS Application
Test Locations	Camp Roberts, CA
Test Objectives	To determine the tracking capability of the application, to determine real world functionality (login, mission creation, mission join, POI creation) of the application. To test GPS accuracy and Google map representation, to test photographic capabilities of the application under commercial wireless connectivity.

The Camp Roberts testing occurred under realistic circumstances, in summer conditions. The day was clear with

no wind and the temperature was between 88 and 92 degrees Fahrenheit. Initial testing occurred in the garrison staging building where the application was tested with multiple logons of users.

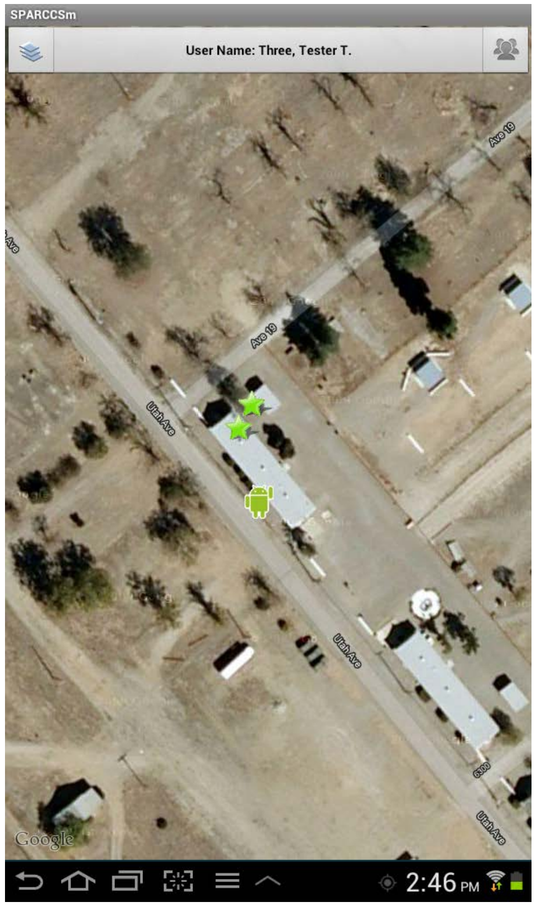

Figure 17. Test Site with Multi-User Logons

As can be seen in Figure 17, three users are logged onto the system as indicated by the Android icon and star icons. These are the three users that were a part of the mission, with two users going into the field in a vehicle and one user staying behind in the building.

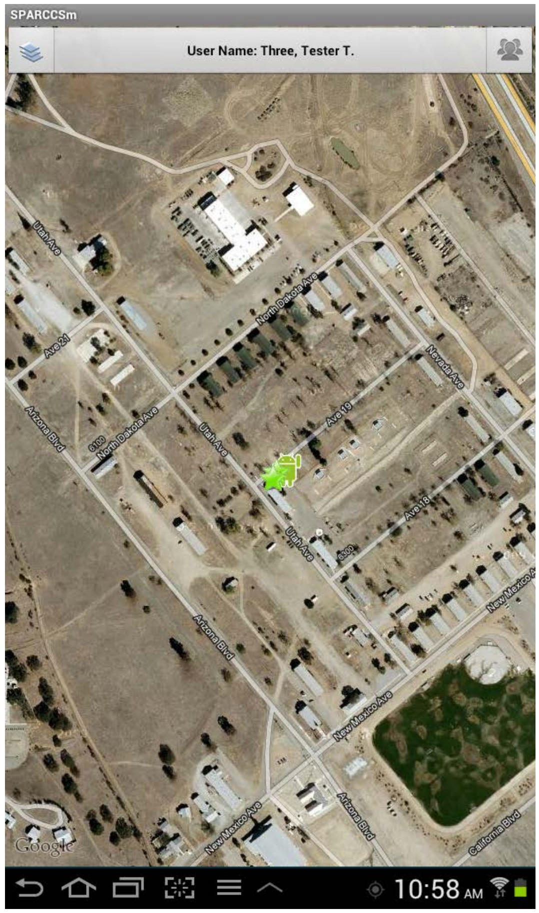

Figure 18. Higher Level Image of Field Location

Figure 18 presents an image of the scenario as zoomed higher above the scene. The mission was created in SPARCCS in the garrison building. The process went smoothly; however it was noted that the mission data input screen, shown in Figure 19, is highly limited in terms of the ability to accommodate text. For example, the Mission Miscellaneous text box only allowed for 32 characters, which is not enough text to clearly provide input for the mission. The Mission Description text box had the same issue. For a situational awareness application data input is critical, and this issue should be rectified to allow for more extensive text input.

Figure 19.   Data Capture Screen for Mission Creation

Once the devices and the application were tested in the garrison building, the tracking test commenced. The test vehicle, a pickup truck, followed a convoy of Army vehicles that were on a mission to test a Raven Unmanned Aerial Vehicle (UAV) in the field. The route went from an elevation of approximately 100 feet above sea level to a location at 767 feet above sea level. One device was left in the building and two devices were located in the pickup truck with the Jetpack system, Figure 20, left image. The Jetpack antenna was mounted on the top of the truck cab, Figure 21, right image.

Figure 20. Vehicle Setup for Tracking Tests

The tracking of SPARCCS was precise throughout the testing. The user icon consistently appeared within 5 feet of the actual location of the vehicle and the movement of the icon was in real time and in relation to the movement of the vehicle. In most cases the icon was on the exact location of the vehicle, and Figure 21 demonstrates this, including demonstrating the correct side of the road of the vehicle. At times when the convoy was stopped, the icon location was measured in relation to the actual location of the vehicle and in all cases the icon was within 5 feet of the actual location and in most cases, the distance was almost exact.

Figure 21. Precision Tracking of SPARCCS at Camp Roberts

During the test, two points of interest were established along the test route. SPARCCS clearly indicated these points at the location of their creation, within 10 feet. Issues with text quantity also arose with the POI screen, as discussed previously with the mission creation text boxes. It is recommended that these text boxes be increased in capacity to accommodate more extensive field descriptions of the POIs. Figure 22 demonstrates the locations of the two points of interest that were created on the mission. Note that the user located at the garrison building is still indicated. Also note that the second device (user) that is logged into the system that is in the tracking vehicle with the first device is not indicated.

This was another issue that was discovered in this field test. During the tracking exercise, only one user is tracked as moving with the vehicle. The other user's star is not visible. Only the stationary user's star is visible during the tracking test. This is a major issue to be rectified; as all users should be seen on the map as each user moves throughout the mission. The incomplete picture of users has the potential to be detrimental to mission success, especially in life safety operations.

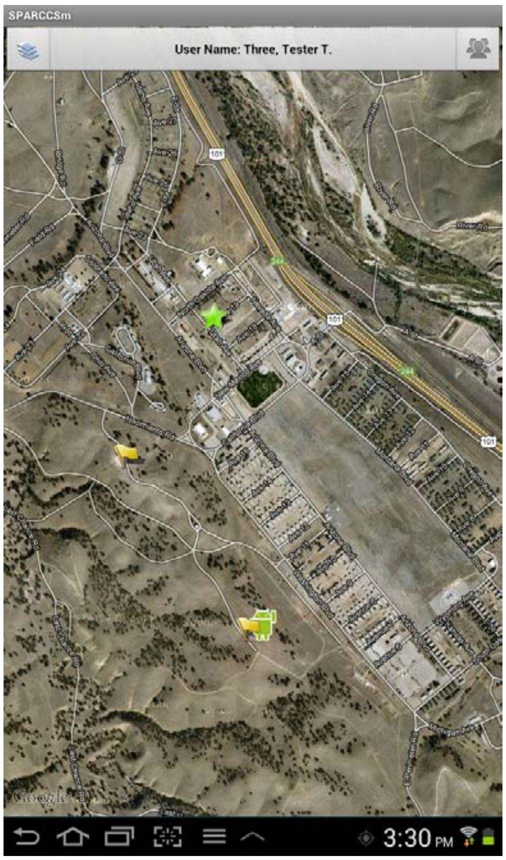

Figure 22. POIs and User Locations at Camp Roberts

The SPARCCS Internet application worked well during the testing. All data captured by the mobile devices was successfully transferred to the Internet application.

Figure 23 demonstrates the Internet application and corresponding mission location, team leader, mission creator, and data gathered on the mobile application.

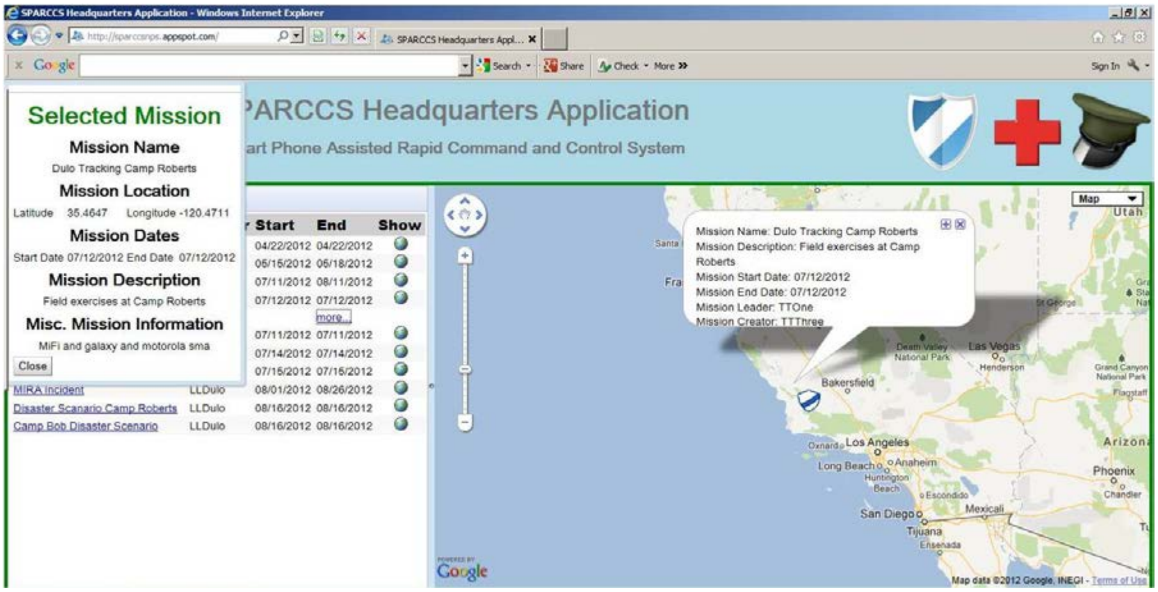

Figure 23. Camp Roberts Mission Main Screen on Internet Application

Finally, the photographic and archival functions of the SPARCCS application were tested. At the second POI a series of photographs were taken of a Raven UAV launch. All photographs were successfully transferred to the Internet application with the correct data associated with them. Figure 24 depicts one of the photographs in the SPARCCS application. As can be seen, the photograph is clear and of a high quality. The data associated with the photograph is accurate. The photograph is associated with the correct POI and is precisely time-stamped in association with the mission.

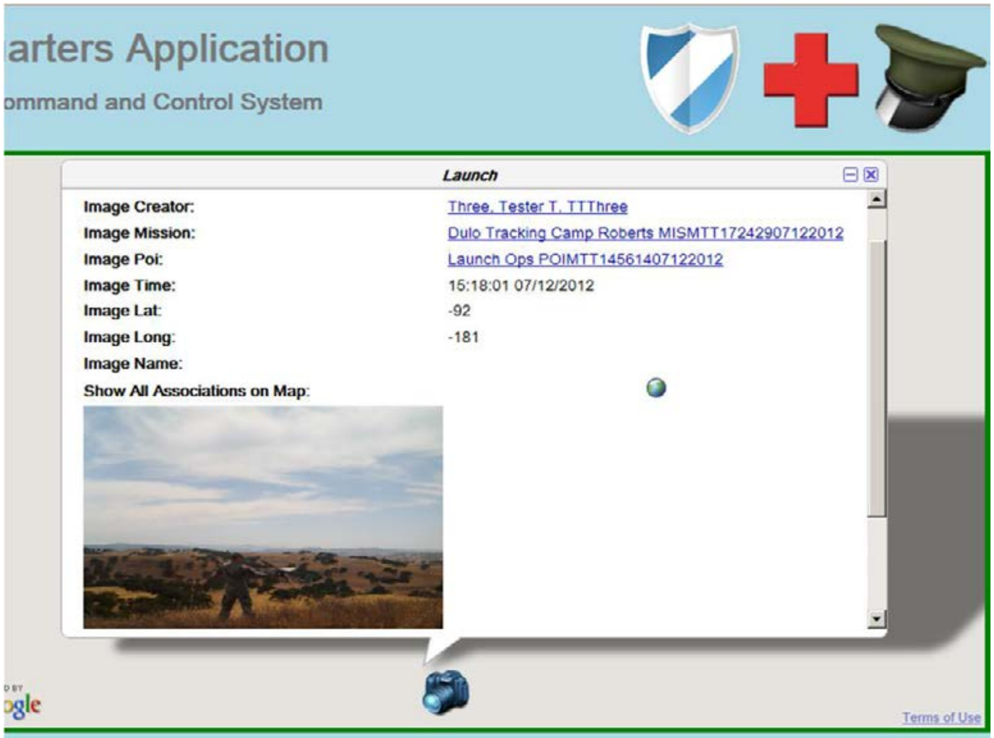

Figure 24. SPARCCS Photographic Imaging Function with POI

Overall, the Camp Roberts initial field test was a success. It demonstrated the power and precision of SPARCCS as well as some issues that need to be rectified in future versions of the software. The testing demonstrated that SPARCCS is a viable application for Army field operations. The issues discovered during this test will not be mentioned further in the following field tests for sake of brevity.

2. Camp Roberts Field Test II

A second round of testing was conducted at Camp Roberts, CA, in August of 2012. The purpose of this round of tests was to test the Wave Relay and WiMax devices in a

real world scenario involving a simulated disaster operation over a larger operational range. Table 11 discusses the details of the testing.

Table 11. Camp Roberts II Testing Details

Test Dates	August 16, 2012
Test Personnel	Donna Dulo,(setup & test) Marcelo Perfetti (setup), Mark Simmons (setup)
Equipment	Galaxy Tablet, Toshiba Tablet, Droid X, Wave Relay Devices, WiMax Devices, Omni-directional antennae, directional antennae, heavy dytu tripods, Toshiba laptop, author's privately owned vehicle
Test Software	SPARCCS Application
Test Locations	Camp Roberts, CA
Test Objectives	To compare and contrast the performance of Wave Relays and WiMax devices as communications bridges and to demonstrate SPARCCS on those networks, to demonstrate the Wave Relay device as a wireless hotspot on a long distance Wave Relay network.

The testing was a part of the larger event on Camp Roberts, the Joint Interagency Field Exploration Research and Experimentation for Local and International Emergency First Responders (JIFX RELIEF). The purpose of the overall test was to test the viability of the Wave Relay and WiMax devices over long-range communications. Our testing used

these devices for SPARCCS as an additional set of testing. The equipment was set up over the entire Camp Roberts installation, spanning over 8 miles. The SPARCCS testing was conducted separately and independently by the author after the devices were set up by the Naval Postgraduate School team. The outdoor temperature was between 85 and 95 degrees Fahrenheit throughout the day.

The scenario consisted of a disaster site, two communications relay hills, and a command headquarters site. Figure 25 demonstrates the sites with photographs and the paths of communications between the sites.

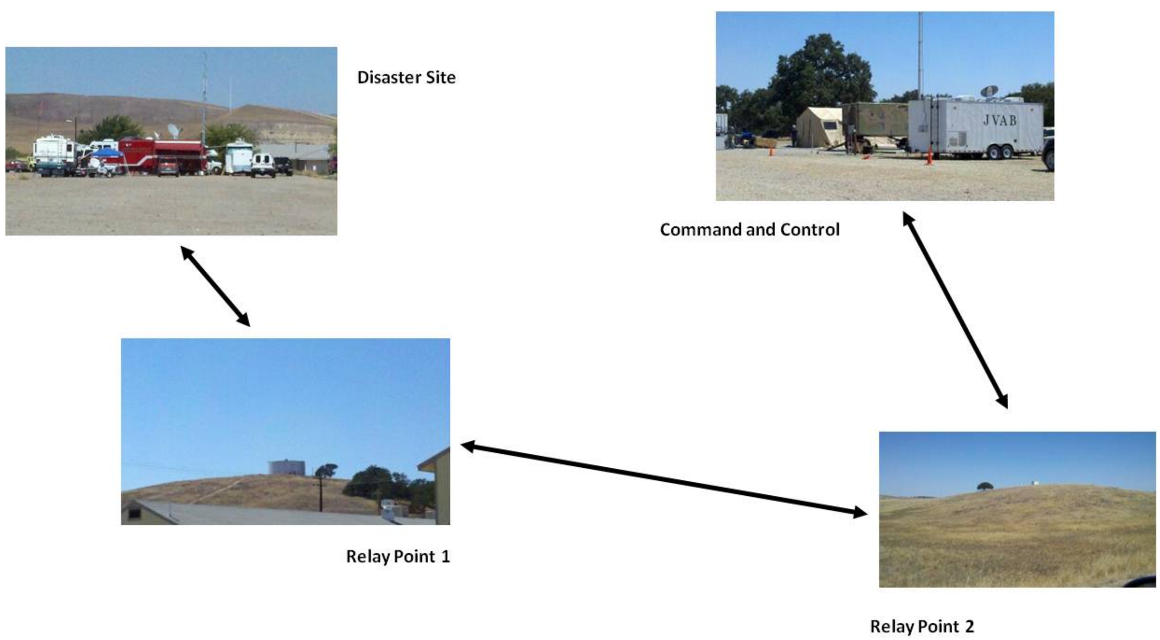

Figure 25. The Communication Sites at Camp Roberts

Each site had a Wave Relay setup and a WiMax setup, independent of each other, stationed about 5 feet apart from each other on heavy-duty tripods. Each network had connectivity through a Hughes INMARSAT Ku-band BGAN device that was located and setup at the disaster site. Figure 26

demonstrates the setup of the communication devices. Appendix A Section B presents selected screenshots of setup screens of the devices.

Figure 26. Camp Roberts Disaster Scenario Setup

The devices were configured at each site and then adjusted over a period of two hours to align them properly. The WiMax devices required precision line of sight while the Wave Relay devices required to be pointed in the general direction of the next device. Figure 27 demonstrates the setup of the devices. This particular setup was at the headquarters site located on McMillan Airfield at Camp Roberts.

Figure 27. WiMAX Device (right) and Wave Relay (left)

During the initial setup testing it was determined that the omni-directional antenna was more ideal and presented significantly greater performance than the directional antenna on the Wave Relays. Figure 28 depicts the omni-directional antenna on the Wave Relay device. Thus, all Wave Relays were equipped with omni-directional antenna for the duration of the testing.

Figure 28. Wave Relay with Omni-Directional Antenna

The device ranges covered extensive distances between the various sites. Figure 29 shows the various distances covered by the devices.

Figure 29. Disaster Scenario Ranges

The readings on the devices were taken by driving up to the site in a privately owned vehicle approved by the Camp Roberts range authority, and plugging in a laptop to take the readings. Appendix A has images that demonstrate the readings screens. There were 2 hours between the 2 sets of readings. It took approximately 50 minutes to do a set of readings by driving to each site. Table 12 contains the data gathered from the two sets of readings taken at the sites.

Table 12. Camp Roberts II Bridge Data Speeds in Mbps

Location	**Wave Relay Round 1/Round 2**	**WiMax Round 1/Round 2**
Disaster Site	5.89 / 5.32	5.76 / 5.01
Relay Hill 1	3.45 / 3.88	3.21 / 3.13
Relay Hill 2	3.73 / 3.64	2.43 / 1.98
C2 HQ	2.68 / 2.51	1.56 / 1.34

As indicated by the data, the Wave Relay had stronger performance as a network. The signal degraded less and the overall delivery to the headquarters site was 1.12 Mbps and 1.17 Mbps greater on the two test rounds. This is a visible indicator of the Wave Relay system's higher sustainment of the signal over the course of 9.1 miles of communications hops, the 6.6-mile link being the constraining factor.

Basic SPARCCS functionality was tested at the headquarters site by using a CAT 5 cable and plugging it into a Toshiba laptop and setting up a small wireless cloud. Through basic functional tests, SPARCCS performed equally on both the Wave Relay and the WiMax devices. Basic tests such as POI creation, GPS functionality, data input, and photographic tests were all successful on both networks with no difference in performance that was noticeable. Thus while the WiMax device network yielded a smaller data rate, the difference was not large enough to show an appreciable performance increase in SPARCCS on the Wave Relay network.

The final test was to demonstrate the Wave Relay device as a wireless hotspot. This was not possible on the WiMax device as it is a bridging device only. A second radio was configured on the device and a second omni-directional antenna was installed. The SPARCCS application was then connected to the network successfully and a mock mission around McMillan airfield was conducted.

Figure 30. McMillan Airfield Photographic Points

Figure 30 demonstrates the two photographic points at each end of the airfield. Figure 31 demonstrates the POI created at the east end of the runway. The screenshots also demonstrate the exceptional range of the WiFi radio on the Wave Relay, which spanned the entire length of the garrison at the airfield. The test also demonstrated that a WIFI cloud could be created at the final headquarters node the of 9.1 miles of hops in a Wave Relay network operating off of a BGAN Internet signal.

Figure 31.   POI, Photograph, and User Location Demonstration

Overall, the Camp Roberts field tests demonstrated the power of both the Wave Relay radios and the WiMax devices as long range bridging devices and the power of the Wave Relay to form a long range network and to form WIFI hotspots that allow applications like SPARCCS to function fully. The combination of SPARCCS and these devices provides a viable communications option for emergency responders and military personnel who require situational awareness over a long distance.

3. MIRA Marina Campus Tests

The Monterey Institute for Research in Astronomy permitted SPARCCS testing at their Marina, CA site. Their site is a four building campus with a large main building,

two shop buildings and an observatory building. The campus is 260 feet by 295 feet and is located on the former Ft. Ord. This scenario was used to demonstrate the SPARCCS application in an urban like setting where responders must transverse between multiple buildings. The tests were conducted in six different sessions over the course of a three-week period. Table 13 provides the details of the tests. The MIRA campus is depicted in Figure 32.

Table 13. MIRA Marina Campus Test Details

Test Dates	Aug 1 – 24, 2012
Test Personnel	Donna Dulo, Tami Huntley, Ada Hynes
Equipment	All listed handheld devices of Table 5, Verizon Jetpack with Antenna, BGAN antenna
Test Software	SpeedTest, SPARCCS Application
Test Locations	MIRA Marina Campus, CA
Test Objectives	To determine the ranges of communications of the Jetpack device and the BGAN device and the performance of SPARCCS on each in a campus setting.

Figure 32. The Marina MIRA Campus

The MIRA campus was drawn on a map and 17 different test locations were established as depicted in Figure 33.

These were the points where data readings were taken. Over the course of six different sessions in a three-week time period, the BGAN and Jetpack were set up and tested through readings at each of these points. Appendix A Section C contains the data for a test run for each of the devices. Four test runs were conducted on each device and the results were similar. Due to space constraints, only one set of each was selected for inclusion in the Appendix.

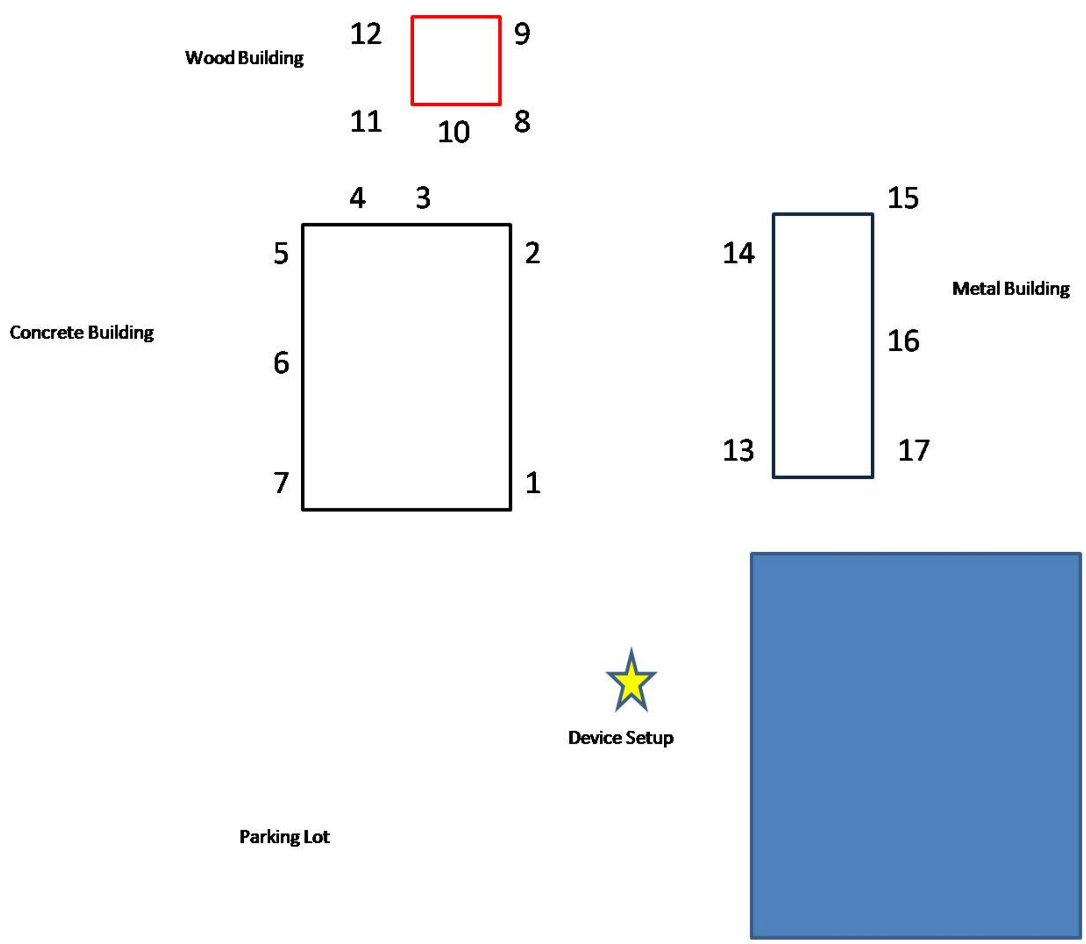

Figure 33. MIRA Campus Data Sample Points

The Verizon Jetpack operated consistently between 3-4 "bars." The weather was consistent among all test dates,

overcast and between 55 and 65 degrees F. The devices were setup in the each location, as illustrated in Figure 34.

Figure 34. Testing Point 1 with the BGAN

The test data, as presented in Appendix A, clearly indicated that the Verizon Jetpack covered the campus easily with strong signals throughout the campus. Of note was the high reading levels around the metal building and the exceptionally high readings next to the observatory antenna. The wireless signal covered the backside of the buildings, although in a degraded state at the far corner of the concrete building.

With the user device directly connected to the BGAN, the signal to the device was weakened or terminated the test device was not in the line of sight of the BGAN antenna. Signals were received approximately 4-5 feet around the corner of the buildings but beyond that no signals were received. This is a strong indicator that the BGAN may not be ideal for other than line of sight. The BGAN signal did stretch the full length of the campus, but only in line of sight. Figure 35 demonstrates the BGAN signal blackout zones on the campus.

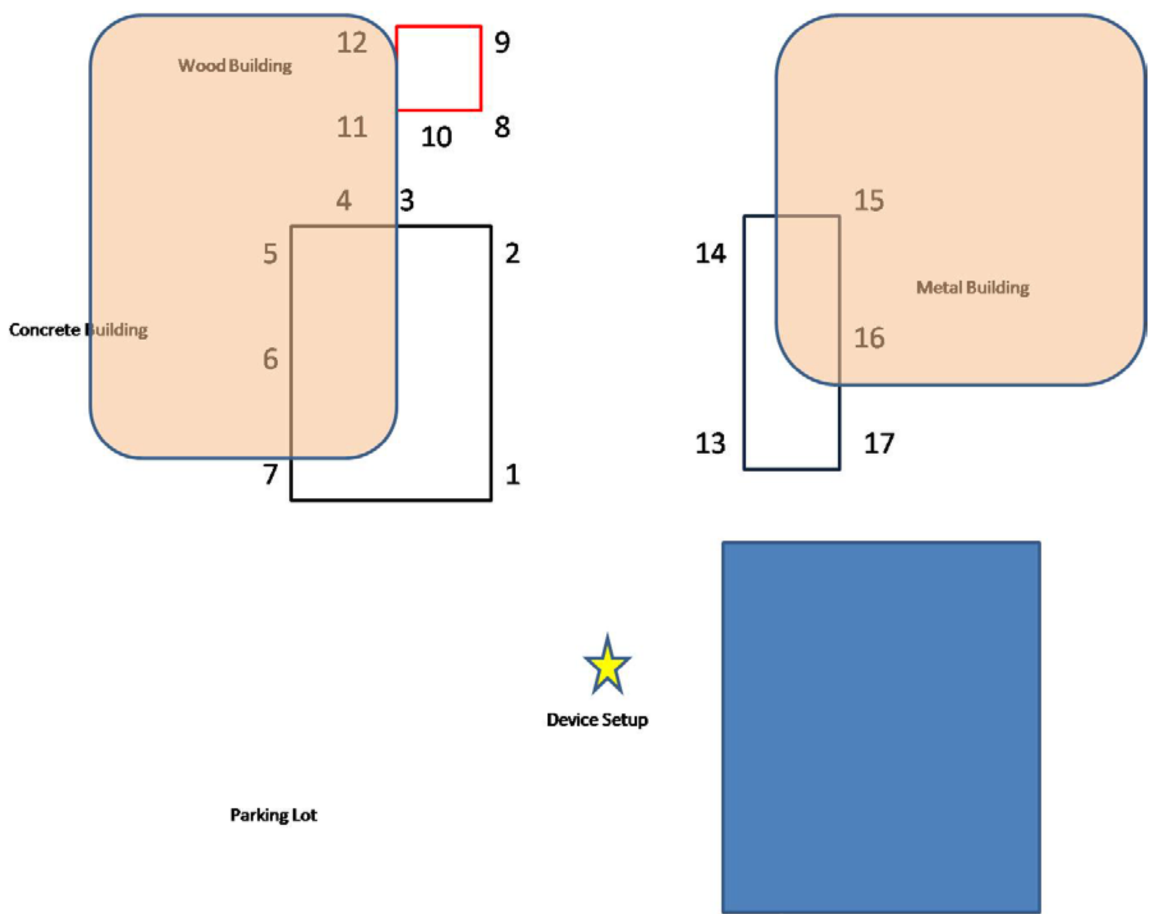

Figure 35. BGAN Blackout Locations

The SPARCCS application was tested at all points of the campus including blackout points. Figure 36 depicts the mission on the headquarters application. The results of the tests suggest that as long as there was a channel of at least 200 Kbps, the SPARCCS application worked fine, including POI creation and data entry, photography, and GPS mapping. The application did not work with data rates less than 100 Kbps and intermittent issues like partial screen painting, application crashes, and application freezing occurred in the range of approximately 100 to 200 Kbps, consistently. When the signal was above 200 Kbps on either the BGAN or Jetpack network, there was no noticeable difference in performance between the two wireless reach-back methodologies.

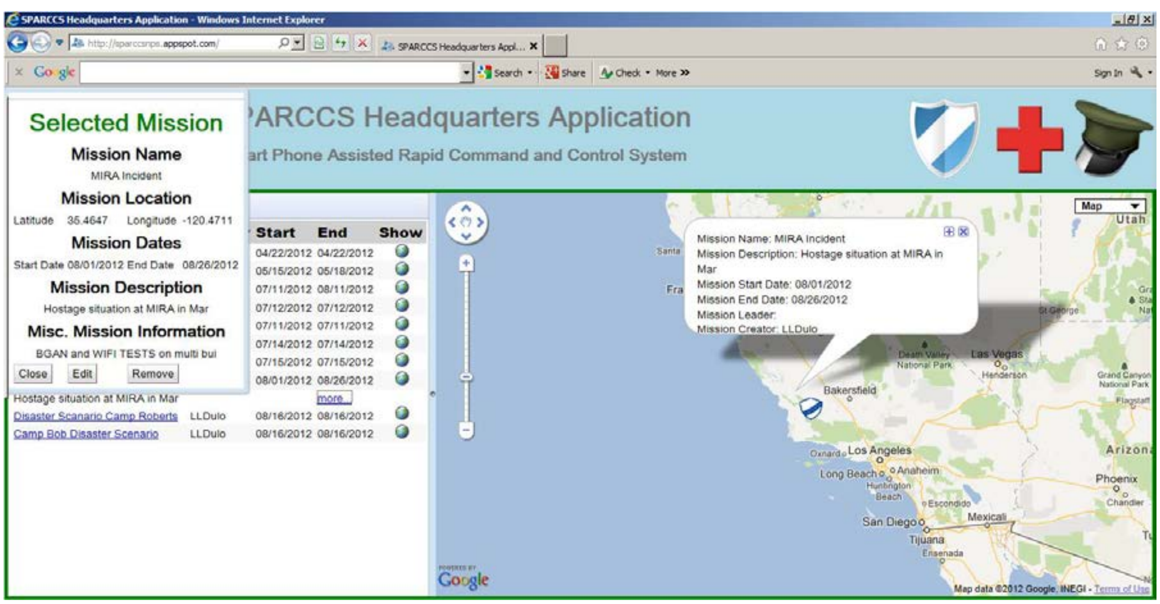

Figure 36. MIRA Mission on the Headquarters Application

The only unique application issue that was noted was the POI location notes textbox, like the mission textboxes described earlier, which could only accommodate a limited amount of text, as demonstrated in Figure 37.

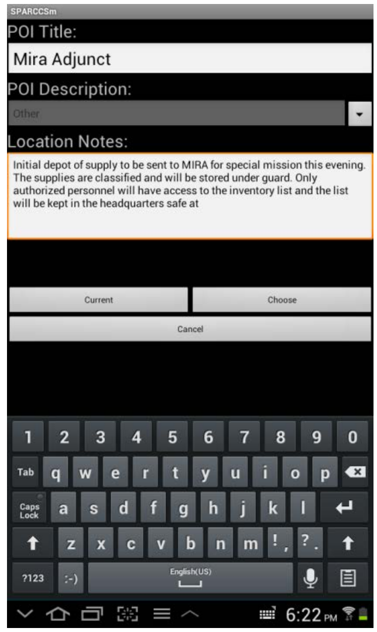

Figure 37. SPARCCS POI Creation

The MIRA campus tests demonstrated the power of the Jetpack and commercial wireless network for an urban SPARCCS application. The BGAN was shown to be less than optimal for situations that have other than unobstructed line-of-sight. Overall, the tests demonstrated the viability of SPARCCS for an urban situation and the performance capabilities of cellular and BGAN WIFI extensions.

4. MIRA Chews Ridge Mountaintop Tests

The Monterey Institute for Research in Astronomy Chews Ridge observatory campus, located at 5000 feet elevation in

the mountains near Big Sur was chosen as a site to test the remote capabilities of the BGAN antenna and the ability of SPARCCS to operate on the WIFI cloud generated by the BGAN. The site is remote, as shown in Figure 38, and there are no commercial cellular signals available. Table 14 provides the details of the tests.

Table 14. MIRA Chews Ridge Campus Tests Details

Test Dates	July 28, 2012
Test Personnel	Donna Dulo, Tami Huntley, Elizabeth Cameron
Equipment	Galaxy and Toshiba tablet PCs, Droid X
Test Software	SpeedTest, SPARCCS Application
Test Locations	MIRA Chews Ridge Campus, CA
Test Objectives	To determine the capability of the BGAN antenna and the SPARCCS application to operate in a remote site at an elevation of 5000 feet.

Figure 38. View from MIRA Site Demonstrating Remote Location

The BGAN was setup at the far end of the MIRA campus. A test range, depicted in Figure 39, with cones laid out every 50 feet was established. Data readings were taken at all points in the test range. Four rounds of tests were taken. All four rounds produced similar results. Appendix A Section D provides the data for one of the test rounds. The elevation ranged from 5003 to 5015 feet with an increase in elevation near the 300 feet marker. This elevation can be seen in Figures 39 and 40.

Figure 39. BGAN Test Range

The data indicates that the BGAN-supported WiFi produced a strong signal for up to 300 feet, where soon after the signal became unstable. This is the exact point of the increase in elevation. After the 300 feet marker, the WiFi cloud generated by the BGAN device was no longer in the direct line of sight of the test device. After 350 feet data transfer was no longer possible.

Figure 40. BGAN Test Range Far End

The SPARCCS application was tested at all points of the test range. Tests included mission creation, POI creation, POI data entry and GPS capabilities. Photos were also taken through the SPARCCS application. The application worked well at distances between 0 through 250 feet. Issues began to develop when the ground began its upslope. These included application halts, application freezing, and failure to paint SPARCCS pages on the device screen. The application worked well on all three test-devices. Figure 41 illustrates the GPS test. Note the remote location of the site.

Figure 41. Remote MIRA Location on SPARCCS GPS Map

The SPARCCS application worked as if it were in an urban area. No differences in performance were noted despite the remote location of the test. This demonstrates that SPARCCS performance is linked to the strength of the wireless signal not the source of the signal or application of the signal to a specific scenario. The tests demonstrated that SPARCCS is a viable tool for missions in the wilderness for both the military and wilderness firefighting. The only issue would be the BGAN line of sight, which must be carefully considered when choosing the BGAN for a scenario like the MIRA Chews Ridge campus.

5. Ft. Ord Concrete Range Field Tests

The purpose of the concrete test range tests was to test the range and performance of the Jetpack and the BGAN on a flat, unobstructed course to determine the range of operation of the devices, and the performance of SPARCCS on the outer edges of device capability. Additionally, the testing of the power capabilities of the devices was determined to give an indication of how long each device could support a SPARCCS operation without being re-charged.

Table 15. Concrete Range Test Details

Test Dates	July 10 - 14, 2012
Test Personnel	Donna Dulo, Tami Huntley, Ada Hynes
Equipment	All listed handheld devices of Table 5, Verizon Jetpack with Antenna, BGAN antenna
Test Software	SpeedTest, SPARCCS Application
Test Locations	Former Ft. Ord, CA
Test Objectives	To determine the linear ranges of communications of the Jetpack device and the BGAN device and the performance of SPARCCS on each.

Table 15 describes the details of the testing which occurred over a five day period on a flat concrete test range on the former Ft. Ord. Figure 42 shows a test team member measuring out the test range with the ranging wheel. Chalk lines were used in conjunction with orange safety cones to ensure that each test day had the same course of

measurement. The range went from 0 to 1500 feet with a measuring point (cone) every 100 feet.

Figure 42. Measuring Out the Test Range

A set of data from two test runs can be found in Appendix A. As can be seen, the BGAN device, with its built in WiFi cloud, had a longer distance of viable signals, 1100 feet as compared to the Jetpack, which had a viable range of 700 feet. The BGAN significantly outperformed its manufacturer’s range of a 100 feet WIFI cloud (Hughes, 2012).

The Jetpack had a strong signal in all of the test runs right up until it hit the edge of its advertised range. As the data indicates, at 700 feet its performance was strong, however at 800 feet it had an initial reading of no signal with a subsequent set of readings significantly lower than previous distances. No signal at all was received at 900 feet and greater.

The BGAN with its built in WiFi cloud had a somewhat inconsistent performance in the range tests. Notice a sudden drop at 400 feet in the test data presented in Appendix A then a large rise at 500 feet. Also, during gusts of wind, which were prevalent on this flat range, the BGAN signal was significantly higher. The BGAN had solid, consistent performance up to 1100 feet before the signal began to degrade.

SPARCCS was tested on both platforms at the outer range of connectivity. The application performed fully with channels over 150 Kbps and performed marginally for channels between 100 and 149 Kbps. Performance indicators of a poor signal were slow application response times, slow or improper screen painting, and inability to send pictures or create a mission or POI. Additionally, SPARCCS tended to halt when there was a significant change in signal; for example, with the BGAN, between 300 and 500 feet, there were several application halts when the upload speeds had a wide variance. In the areas with consistent signals over 150 Kbps the SPARCCS application worked well in all aspects of functionality.

A final round of testing concerned the battery power of the two wireless devices. In the field it is critical to understand the power limitations of the devices so that mission planning can accommodate recharging sessions or device replacement. Table 16 presents the data for battery testing. The rounds were conducted on different days and the devices were in operating mode during the tests.

Table 16. Device Battery Life

Device	**Round**	**Charge Time in Operation**
BGAN	1	5 hours 23 min
BGAN	2	5 hours 35 min
Jetpack	1	2 hours 4 min
Jetpack	2	2 hours 12 min

As can be seen, the BGAN has a significantly longer life than the Jetpack. This particular BGAN device had a battery only 3 months old, so it may be considered new. However, the manufacturer (Hughes, 2012) claims the battery life to be 6 hours, so this device fell short of this claim.

The Jetpack had a shorter battery life. However, its recharge time was only 30 minutes compared to several hours for the BGAN. In addition, the Jetpack could be charged easily with a car’s lighter adapter, as opposed to the 120 volt requirement for the BGAN, so the jetpack could be brought back online faster than the BGAN.

Overall, the concrete range tests demonstrated the distance of signals and battery limitations of the jetpack and BGAN; critical information when planning a SPARCCS mission. The data collected serves as a guide to mission planning and selecting the proper device for the particular mission tasking.

6. Ft. Ord Wildland Scenario Field Tests

The Ft. Ord Wildland field tests were similar to the concrete test range tests with the difference being natural shrubbery occurring along the test path. In these tests, a 1500 feet test range was measured out through a patch of shrubbery and trees to determine signal strength and decay

for missions involving wildland operations for military or emergency personnel. Table 17 describes the details of the testing.

Table 17. Wildland Range Tests Details

Test Dates	July 15-21, 2012
Test Personnel	Donna Dulo, Tami Huntley, Ada Hynes
Equipment	All listed handheld devices of Table 5, Verizon Jetpack with Antenna, BGAN antenna
Test Software	SpeedTest, SPARCCS Application
Test Locations	Former Ft. Ord, CA
Test Objectives	To determine the ranges of communications of the Jetpack device and the BGAN device and the performance of SPARCCS on each in a wildland setting with trees and shrubbery as obstacles.

The tests were conducted in a large, open woodland area on the former Ft. Ord during a 7-day period. The test setup was identical to the concrete range with points of measurement every 100 feet. The area was relatively flat so that elevation/line of sight would not be a factor in the tests. Figure 43 shows the test range.

Figure 43. Wildland Test Range

The data from the wildland tests can be found in Appendix A. The data was significantly different than the open flat range test data. The BGAN saw performance decay once medium density shrubbery was present. These were low hanging trees, as depicted in Figure 43. As can be seen, the trees did not have large trunks, just low handing branches that filled the area with foliage. Once the foliage density increased the BGAN-provided WiFi signal rapidly decayed. Thus, through 200 feet of shrubbery the signal went from “strong” to “nothing,” indicating that foliage obstacles can seriously impact the BGAN unit’s use in the woods. Thus, it can be concluded that the BGAN’s WiFi signal will degrade upon the commencement of medium density shrubbery and will completely degrade soon after.

The Jetpack, conversely, demonstrated little difference between its concrete test range readings and its

wildland readings. Both tests demonstrate a 700 feet solid signal radius. This indicates that the shrubbery and foliage did not have a significant performance impact on the Jetpack signal. This is a critical piece of information as it indicates that the Jetpack is a more viable option for communications in a wooded area. It also raises the issue of frequency range, as higher frequencies are more sensitive to foliage than lower frequencies. The use of SPARCCS in a wildland setting should be carried out with a device with the lowest frequency range.

SPARCCS performed fully with signals over 150 Kbps and performed marginally between 100 and 149 Kbps as also indicated in the concrete test range tests. Performance indicators for a poor signal were slow application response times, slow or improper screen painting, inability to send pictures, and inability to create a mission or POI. With the Jetpack, the application performed well in the midst of the foliage within the 700 feet range, as opposed to performance with the BGAN, which showed application issues within the initial 200 feet of the foliage line.

Thus, the wildland tests clearly indicate that the selection of a BGAN or Jetpack must rest on the density of the area of the mission. It will also rest on the signal for the cellular service. During these tests the jetpack had a 3-4 bar signal strength. However, in remote locations the BGAN may be the only option. In this case, care should be made to plan out the BGAN range with obstacles in mind.

7. Vehicle Distance Tracking Tests

The vehicle tracking tests were a more lengthy extension of the initial Camp Roberts tests. The purpose of

these tests was to demonstrate the long-range capabilities of SPARCCS to support a mission that required responders to travel a long distance. Table 18 describes the details of the tests.

Table 18. Vehicle Distance Tracking Details

Test Dates	July 18, 2012
Test Personnel	Donna Dulo, Tami Huntley
Equipment	Galaxy Tablet and Droid X
Test Software	SpeedTest, SPARCCS Application
Test Locations	Monterey County, CA
Test Objectives	To determine the tracking ability of SPARCCS on a long range mission.

The tests were conducted on two California highways, from Ft. Ord to Gilroy, California. Several stops were made along the way to take readings. Stops were made in parking lots to be able to clearly measure the precision of the Google mapping in SPARCCS through parking lot lines. The tests took two hours to complete.

The tests consisted of three devices logged onto the same mission using Jetpack connectivity with an external antenna mounted on the exterior of the vehicle. The devices were maintained by the vehicle passenger. Screenshots were taken at specific test points. The tracking of the vehicle was observed by the tester in the passenger seat to ensure accuracy and precision with the mapping. Figure 44 demonstrates the initial location of the tests. Note the

time stamps on the screenshots that indicate time travelled during the testing. The test drive began at approximately 8:30 PM.

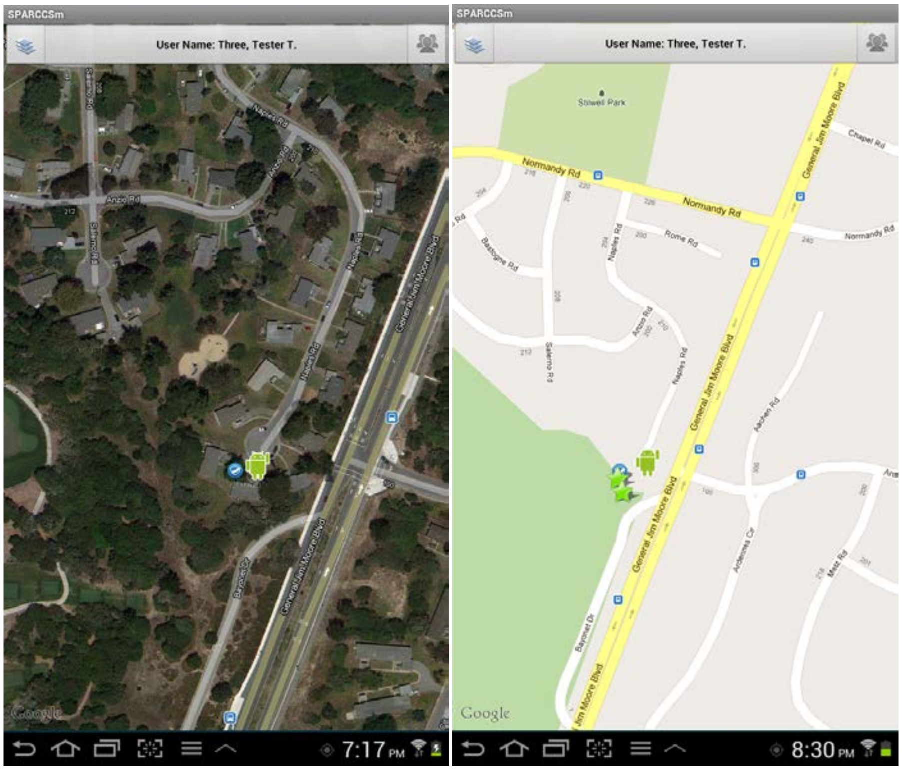

Figure 44. Initial Location with Three Devices on the Mission

At approximately 8:55 the vehicle arrived in Prunedale, CA and a set of screen shots were taken, as shown in Figure 45. SPARCCS tracked perfectly from the beginning of the trip to this site. Note that the user icon is in the exact parking spot as the test vehicle. The POI flag was slightly off location by about twenty feet. The POI information was collected, input, and displayed well on the SPARCCS Internet application. The SPARCCS application worked fluidly through the entire leg of the trip with no breaks in connectivity or application freezes or halts.

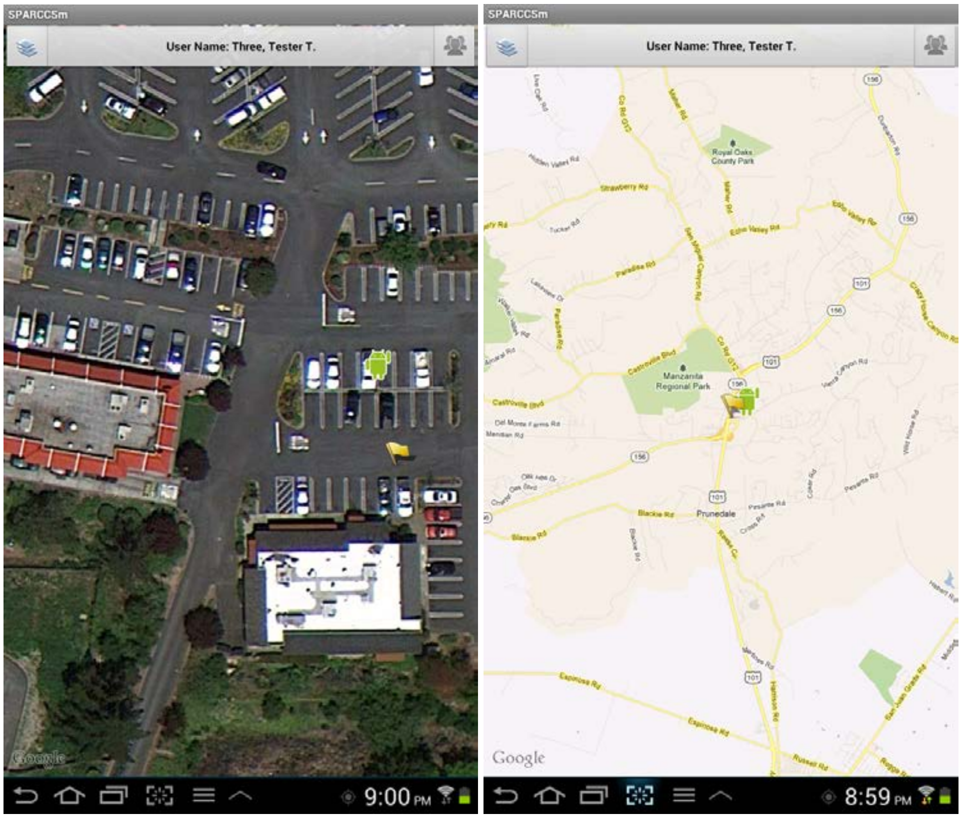

Figure 45. First Test Location

At approximately 9:30 PM the test vehicle arrived in Gilroy, CA, with all three devices still tracking with no breaks in connectivity for any of the three. Figure 46 demonstrates the screenshots from this location. Note that in this instance the user icon and the POI icon are in the exact location of the vehicle in the parking lot.

The tests indicated that the SPARCCS application is robust in its tracking ability over long ranges. The tests also indicated that the mapping of the icons is quite precise, even after over an hour of operation on a mission. The only issue with the application is the lack of tracking of the other team members on the mission. The initial screen shows the other team members but they are not tracked on the screen. This issue should be improved in

future versions of the software, as the precise location of all team members is critical for safety and security reasons.

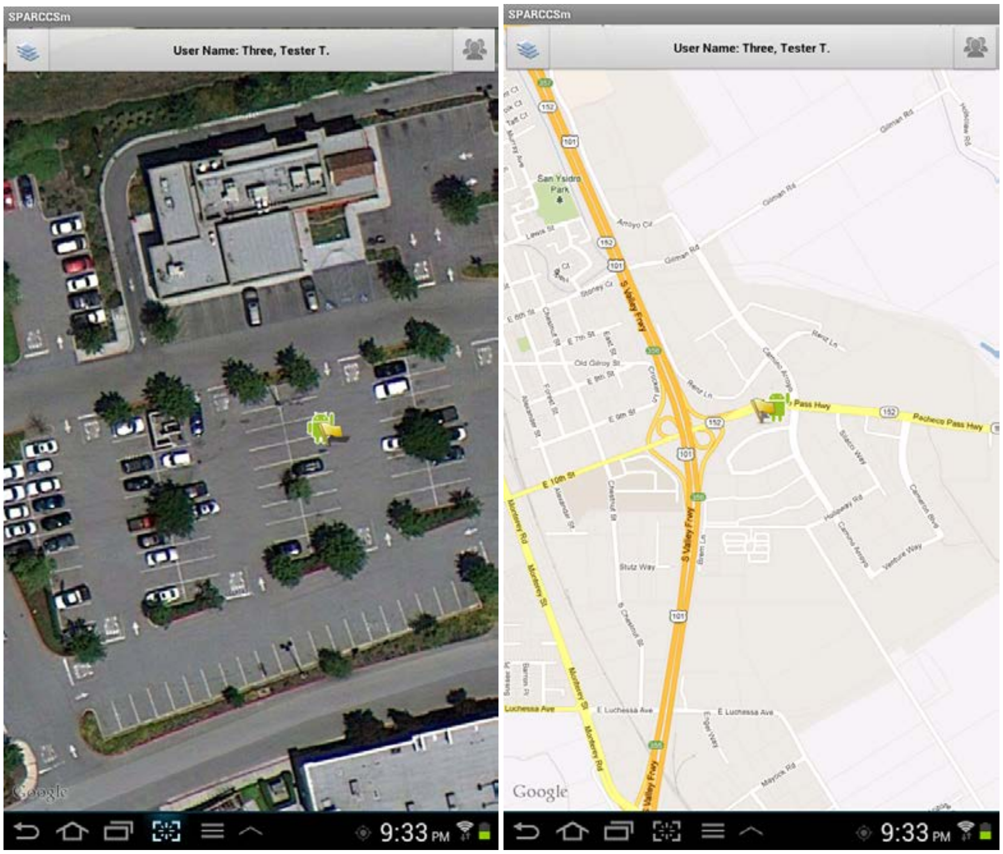

Figure 46. Second Test Location

Overall, the tracking tests demonstrated the power and precision of the SPARCCS application in a long duration vehicle-tracking mission. Through precise tracking, the SPARCCS application can provide valuable information to a command and control station, improving situational awareness for all mission members.

C. TESTING CONCLUSION

The controlled and field tests demonstrated the applicability and viability of the SPARCCS application in a variety of scenarios. From urban campuses to remote sites high in the mountains, the SPARCCS application functions properly to deliver data and photographs as well as GPS maps and precision locations to users to improve situational awareness. Overall, SPARCCS performs well depending on the strength of the wireless signal. The source of the signal, in terms of a specific device, does not matter as long as the device produces a viable WiFi cloud. The next chapter summarizes the testing process and provides clear recommendations for the use of the SPARCCS application as well as future recommendations for the testing of the system. It also provides a summary of conclusions for the testing program.

V. CONCLUSIONS AND RECOMMENDATIONS

A. TEST CONCLUSIONS AND RECOMMENDATIONS

The testing in this thesis brought up critical points regarding the use and development of the SPARCCS application. It can be concluded that the application is a viable concept that applies to civilian emergency services as well as the military. The application's concept could even be applied to academia and the general public, such as for field exploration, scientific wilderness missions, or recreation with large groups.

The SPARCCS application already shows promise as a robust application, even at this stage of development. It works well in a variety of scenarios and works on all of the wireless platforms tested. The mobile application functions equally well on smart -as well as all sizes of tablet PCs. The browser-based Internet application worked well on all evaluated computing devices, including Apple and PC computers and various tablets.

The SPARCCS application is still in development. As such, the testing was designed to find issues and errors that can be rectified in future versions of the software. The testing succeeded in this endeavor. The testing also demonstrated the benefits and limitations of various wireless technologies that SPARCCS may employ.

Table 19 takes the findings and conclusions of the testing and presents a set of recommendations for future use and development of the SPARCCS application. It provides some key recommendations gleaned from the testing of the SPARCCS application and associated wireless devices.

Table 19. SPARCCS Recommendations

Number	Recommendations
1	Utilize SPARCCS on the Android OS of 2.3 to 4.0.3.
2	Utilize the SPARCCS Internet application on networks that do not block the Google Appspot applications. Military networks such as the “army.mil” network block such applications. This should be considered before the mission commences.
3	Utilize SPARCCS on the proper wireless platform to optimize application performance.
4	For campus settings, cellular wireless may be more optimal than BGAN.
5	For wildland settings, cellular wireless may be optimal if there is a signal.
6	For flat unobstructed locations, the BGAN may provide the best distance performance.
7	For remote locations, the BGAN is optimal and should be utilized.
8	For long range network bridging, Wave Relay devices outperform WiMax devices, so they should be the first choice in equipment.
9	Wave Relay devices provide superior hotspot coverage, but can only be used if a 120 volt power source is available, or a vehicle inverter, or a Persistent Systems power enabled backpack is used. Therefore planning should accommodate this power requirement.

Number	**Recommendations**
10	BGAN units provide longer service than Jetpacks by over 3 hours so for longer operations the BGAN should be utilized if practical.
11	The Jetpack provides excellent support for long range, continual tracking and should be used for long range tracking missions if service is available on the route.
12	The BGAN has an optimal range of a 1100 ft radius on a flat area with no obstructions and should be the first choice for this mission scenario.
13	The Jetpack has an optimal range of 700 ft with or without obstructions and should be used if buildings or shrubbery are in the mission area.
14	Both the Wave Relays and the WiMax devices can form long-range networks of over 9 miles and should be used for such distances if the mission requires long-range networking.
15	The BGAN antenna requires near line of sight for optimal signal reception, so mission planning must accommodate this issue.
16	The Jetpack does not require line of sight and may be more optimal than the BGAN in congested urban or wildland settings.
17	WiMax bridges require line of sight, Wave Relay bridges do not. This must be considered in mission planning.

Number	Recommendations
18	Wave Relay hotspots do not require line of sight, which should be considered when planning mission device requirements.
19	The SPARCCS application is fully functional with a wireless signal of at least 150 Kbps. Mission planners must take this into consideration when planning missions and wireless device usage.
20	Signal decay has the following signs on the SPARCCS application which should be noted by all users of the system to be able to diagnose this issue: application halting, application freezing, incomplete interface painting, inability to transfer photos or data, improper navigation.
21	SPARCCS can be used equally well on smart-phone or tablet PCs. Optimally, the 7” should be used for ease of handling, screen visibility, and navigability of interface.
22	The mission creation function should be re-engineered to eliminate navigation errors in the application.
23	The team member icons should have the ability to be tracked on other team member’s maps. This should be programmed into future versions.
24	Additional space for text should be provided for all text acquisition functions such as mission creation functions, POI functions, image descriptions, etc. to increase data collection

Number	Recommendations
	capabilities.
25	The DORCCS acronym should be replaced with the SPARCCS acronym in all text message boxes.

B. RECOMMENDED FUTURE TESTING

This testing of SPARCCS was only the initial testing for the application. As the application matures, further and more advanced testing will be required. The following are recommendations for future testing.

1. Human Factors Testing

The SPARCCS application runs on both hand-held devices and tablets. The Internet application runs on any device that has Internet connectivity and a supported browser. The implementation of human factors engineering is crucial for an optimized application, as in the field users cannot be burdened with navigation issues, color issues, lighting issues, and other issues of interactive functionality.

A complete human factors testing program would ensure that both applications have user interfaces that are tailored to the human body, such as the location of buttons on the screen or colors used. Human factors engineering helps optimize applications, and as such, would help maximize the potential of the SPARCCS application for a wide range of missions and functions in the real world.

Since SPARCCS is a field application, many missions may have users wearing gloves, eye protection, or other bodily protection. An un-optimized SPARCCS application may compound the usability issues by which the users are

already challenged. This is why human factors testing is critical to the validation of long term usability and performance of the SPARCCS application.

2. BGAN on the Move Testing

The BGAN device was tested in a stationary setting; it does not function well in a moving vehicle due to satellite tracking issues. The BGAN-on-the-Move is a device that rests on the top of a vehicle, attached by a magnet, which continually tracks the INMARSAT satellite and can provide an Internet cloud for a convoy of vehicles over the range of several hundred feet.

Future testing of SPARCCS should utilize the mobile-BGAN device, as remote locations may not have the cellular signal capabilities that were tested in this thesis. Remote testing over long distances of the BGAN-on-the-Move device would add another communications option to a SPARCCS mission application.

3. Cellular Vendor Tests

The Verizon Jetpack service was tested throughout this thesis. However, there are several other vendors that have the same or similar service. Future testing should include a similar assessment of various vendors' services and the performance of SPARCCS on that service. Since SPARCCS is an application that can be used across the country by police and fire services as well as military, cellular service may vary from jurisdiction to jurisdiction. By having data on the other cellular services, users of the application can plan for use at incidents with the optimal service at the location of the incident.

4. Wave Relay Mission Packs

One of the major limitations of the Wave Relay system, as tested in this thesis, was the power requirement for the radios. In essence, the radios must be tethered to a location or a vehicle with an inverter in order to function. The manufacturer, Persistent Systems, has a field pack for the devices that consists of a vest system with a battery pack and a carrier for the radios with antenna slots. By using this pack, the Wave Relay system is mobile and individual members of the SPARCCS mission would have their own radios that could act as a bridge or a hot spot. In essence, a human-hosted, ad hoc, wireless mesh network would be able to be constructed to improve wireless connectivity for the mission team, which would greatly expand the range of the SPARCCS application.

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APPENDIX A. SAMPLE TEST DATA

A. CONTROLLED TESTS

Table 20. Wireless Device Control Tests

Device	Date	Location	Personnel	Notes
BGAN	Jun 8 2012	NPS	Dulo, HFN	The BGAN device was tested at the NPS campus to ensure proper functionality. The device failed at first but it was noted that a tree branch, approximately 20 feet from the device, Figure 11 was within the line of sight of the device and the Inmarsat satellite. Shifting the device over 3 feet alleviated this problem. The system checked out as fully functional
BGAN	Jun 14 2012	CalFire	Dulo, HFN, CalFire	The BGAN device was tested with several contingencies. The sky was completely overcast but the device connected properly with the satellite. The device

Device	Date	Location	Personnel	Notes
				did not function through a window screen. The device did connect with the satellite through a window that did not have a screen. The device did not connect to the satellite when a building blocked part of the line of sight with the satellite. The device experienced connectivity problems when being pointed at the satellite through a wire fence. The optimal method to acquire strong satellite connectivity was determined to be the use of the audio strength signal. Using the visual strength bars on the device display provided less precision in device pointing.
WR, WiMax	Jun 21 2012	CalFire	Dulo, HFN, CalFire	The wave relay radios were set up in the classroom and in the extended parking lot of the CalFire campus. The

Device	Date	Location	Personnel	Notes
				radios were able to operate in bridge mode as well as wireless node mode. Four wave relay radios were tested and connected into a wireless mesh network and were all able to communicate with each other properly. No communications issues were noted. The only issue with the devices was that they required 120 volt power and as such mobility in testing the devices was highly limited to the length of the power cords and the availability of wall power outlets. Omni directional antennae were used and thus line of sight was not required for the radios. All worked well in bridge mode and as wireless hotspots. The BGAN device was used as the Internet

Device	Date	Location	Personnel	Notes
				connectivity device and connected well with the wave relay radios. The WiMax devices were tested in the classroom and in the parking lot. Point to point bridge communication between devices was established and a small mesh network was established with good communications. Again, power cord mobility was an issue with the WiMax devices. The devices also required strict line of sight with the other devices in the network. The BGAN device was used as the Internet connectivity device and connected well with the WiMax broadband bridges.
Jetpack, BGAN	Jun 23 to 27 2012	Outdoor Test Lab	Dulo	The outdoor test range, Figure 12, was used for the final device tests. A test range of 200 feet

Device	Date	Location	Personnel	Notes
				was set up in the outdoor test range to ensure that the devices worked well with the Android systems. The Jetpack functioned well at a signal strength of 4 bars and exchanged viable data at all points from 0 feet through 200 ft at 25 foot increments. The BGAN device, Figure 13, connected properly to the satellite despite the fact that tree lines were in the line of sight. The use of an external compass was introduced in this test. The BGAN device has a design flaw, where the aiming compass is on the bottom of the device making it obscured when the device is in use. An external compass assisted well in the pointing of the device and made satellite

Device	Date	Location	Personnel	Notes
				acquisition more rapid and accurate. The BGAN device exchanged viable data as demonstrated at each step in the test range. The wave relay devices were not tested in the outdoor test range due to the fact that 120 volt power was not available. This is a distinct issue with the wave relay devices and one that needs to be addressed before the wave relay radio is integrated into SPARCCS use.

Table 21. Basic Application Tests

Test	Device	Results
Account Creation	All 5 mobile devices, Toshiba laptop	User accounts were created with all 5 of the mobile test devices on the mobile application as well as through the Internet application. In general there were no problems with account

Test	Device	Results
		creation. To be noted, the acronym DORCCS continued to appear in various message boxes. This could possibly confuse a user and thus the code should be reviewed to replace all instances with the SPARCCS acronym. On the tablets the account creation worked fine but on the smaller smart phones, the text boxes were small and it was difficult to navigate the screen. Several attempts to create the user accounts had to be taken due to the difficulty in scrolling up and down the small screen which was made smaller with the screen keypad. All accounts appeared on the Internet application precisely as inputted. Creating the accounts on the Internet application posed no difficulties.
Login	All	Both applications went through login testing which was a basic test to see if accounts created were viable and facilitated login into the system. All devices were able to login to the system on both applications well and

Test	Device	Results
		without incident. One note: at a low signal, the SPARCCS mobile login screen is not painted properly on the screen. This was tested thoroughly and it appears that at 0-1 bars, this issue arises. With 1-5 bars this does not arise. Through rigorous testing of this issue it can be confirmed that this is a signal strength issue only, not a SPARCCS application issue. This should be noted in SPARCCS troubleshooting documentation.
Mission Creation/Join	All	The mission creation function worked successfully on both applications. However, in some cases it was difficult to navigate from the user screen to the mission creation screen and back again. For example, when a mission was created or joined, the back navigation brought the user back to the mission creation/join screen and the only option was to go back into the mission creation page. To solve this issue the application had to be restarted. This occurred usually when a new mission was

Test	**Device**	**Results**
		created and then a user tried to join the mission shortly after. This appears to be a design issue in the application, and improved navigation in the mission create/join page should solve this issue.
Point of Interest	All	The point of interest function was tested on all devices. This function worked well on all devices without incident. The POIs created appeared on the Internet application as inputted and the Google map was updated with the POI symbol at the exact point of the POI.
Photographic Evidence	All	The photographic function was tested on all devices. In each instance a photograph was taken and inputted in the system. In all cases the photograph was successfully transferred and visible in the Internet application. The photographs were clear and of high quality. The camera icon also appeared on the Google map at the point of the image acquisition. No issues were discovered after extensive

Test	Device	Results
		testing of this function.
Google Map Presentation	All	All devices were tested with their GPS capabilities in relation to the SPARCCS application. All instances with the Google maps presented precise maps with the current user icon of SPARCCS located within 5 feet of the actual location of the device. In all cases, the Google map was refreshed properly when the user moved location with the device. No issues were uncovered concerning Google maps or GPS issues.

B. CAMP ROBERTS FIELD TEST TWO

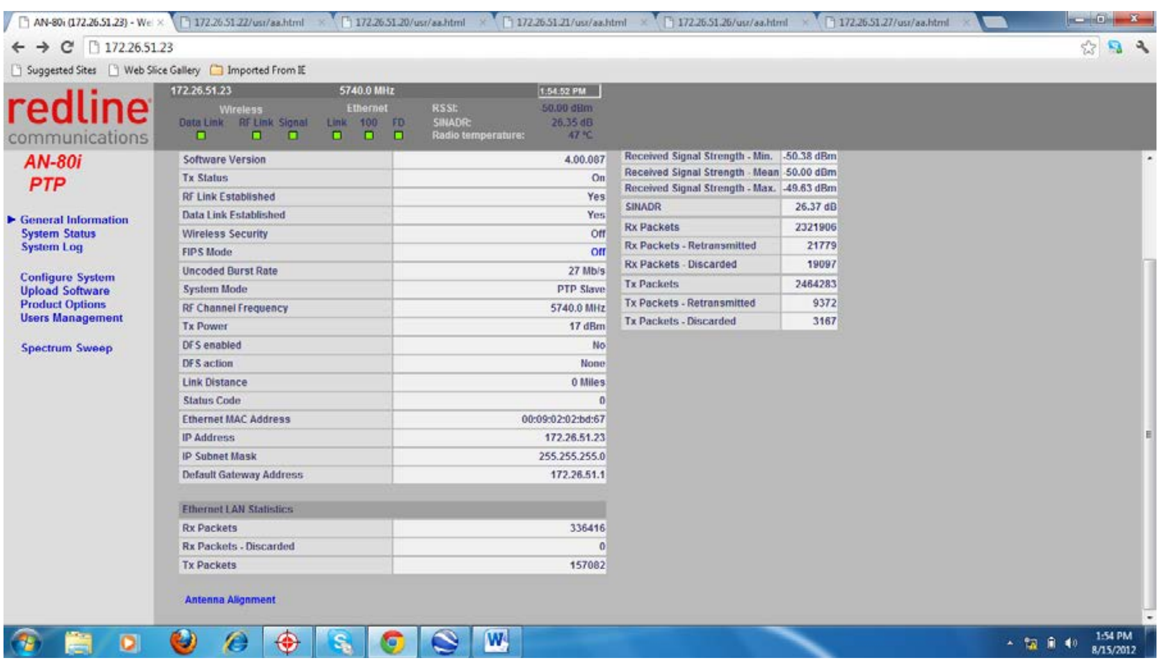


Figure 47. Sample WiMax Information Screen

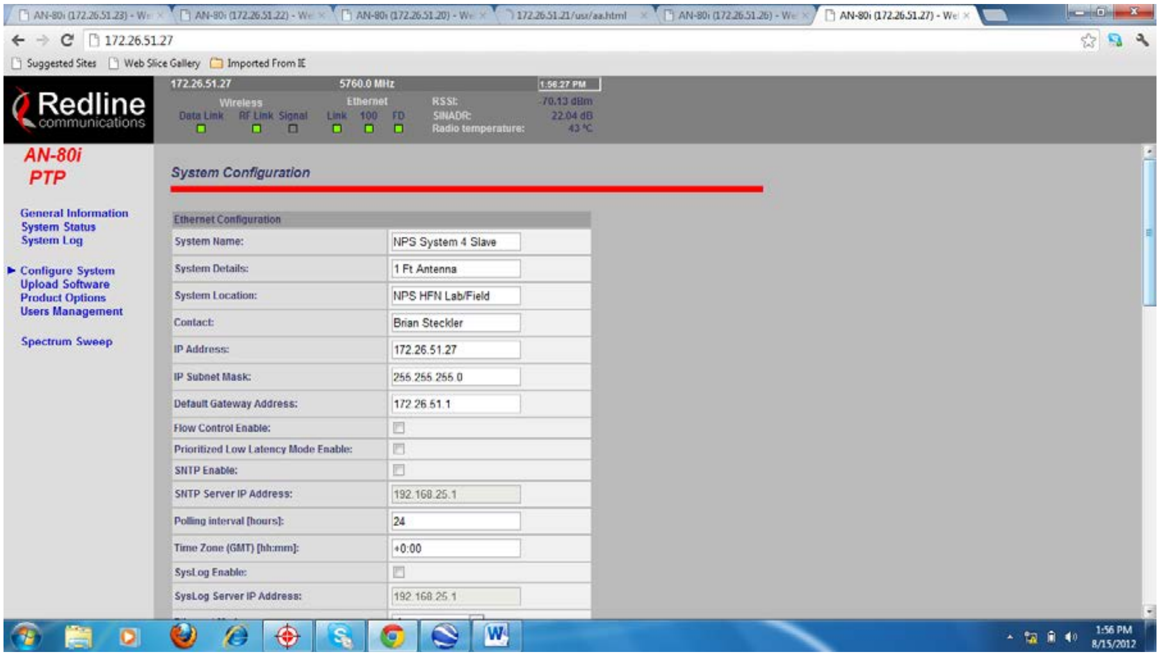


Figure 48. Sample WiMax Configuration

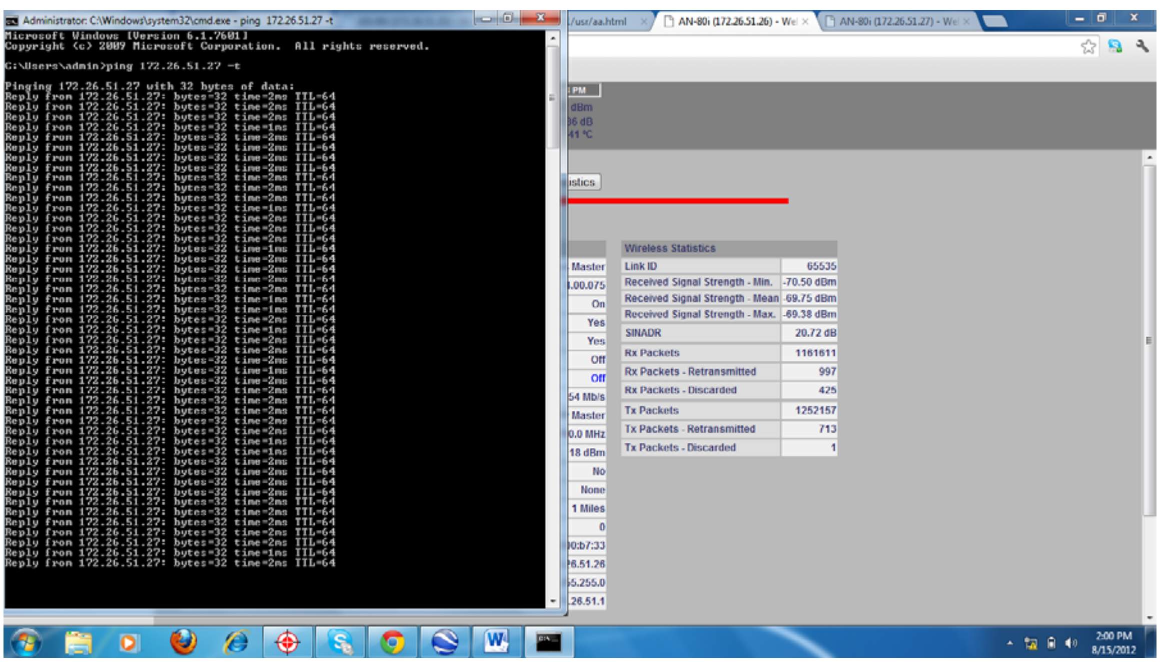


Figure 49. WiMax Ping Demonstration

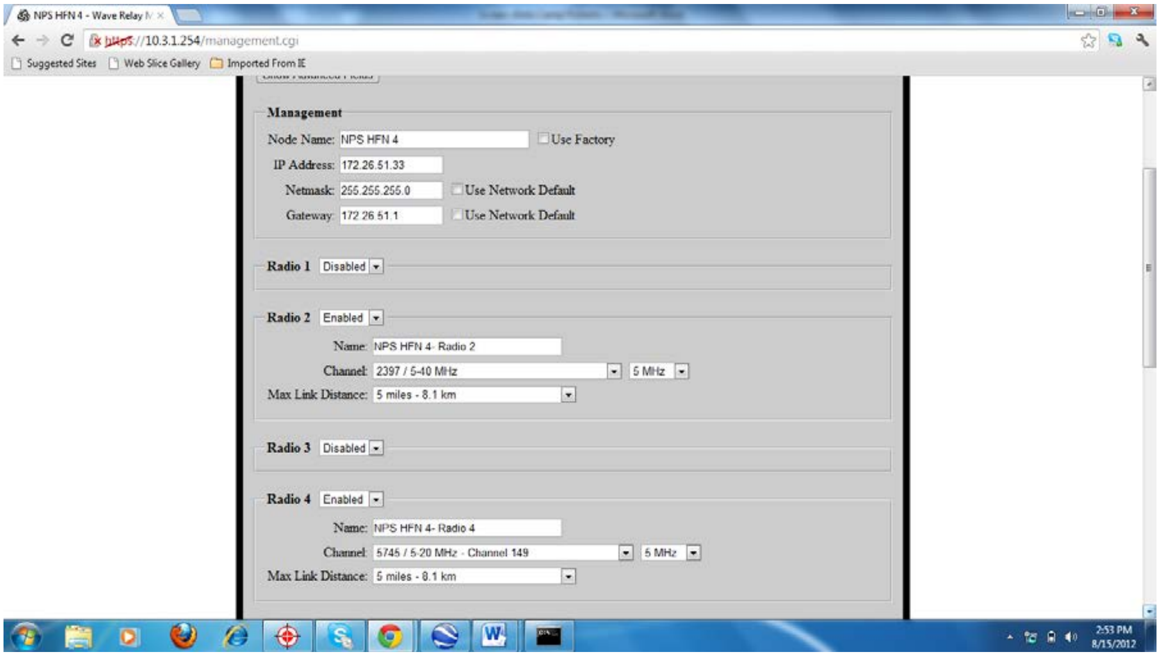


Figure 50. Sample Wave Relay Setup

C. MIRA MARINA CAMPUS

Table 22. MIRA Jetpack Data in Kbps

Location #	**Upload Speed**	**Download Speed**	**Notes**
1	714	752	About 5 foot elevation
2	479	613	Elevated line of sight
3	387	344	Back midpoint of concrete building
4	311	598	Back ¾ of concrete building
5	189	111	Distant corner, noticeable degrade of signal
6	850	876	Significant improvement in signal
7	853	750	Line of sight

8	612	662	Line of sight
9	641	651	Line of sight
10	767	521	Midpoint of wood building
11	1263	2236	Note: next to building antenna
12	517	115	Far end of wood building
13	412	450	Line of sight metal building
14	917	924	Line of sight metal building
15	458	313	Far end metal building
16	501	531	Midpoint far side metal bldg
17	895	1146	Near line of sight

Table 23. MIRA BGAN Data in Kbps

Location #	**Upload Speed**	**Download Speed**	**Notes**
1	536	171	About 5 foot elevation
2	530	179	Elevated line of sight
3	228	176	Back midpoint of concrete building
4	0	0	Back ¾ of concrete building No signal after 3 reading attempts
5	0	0	Distant corner concrete building. 3 reading attempts.
6	0	0	Midpoint of concrete bldg far side. 3 reading attempts.
7	288	150	Line of sight

Location #	Upload Speed	Download Speed	Notes
8	372	184	Line of sight
9	201	226	Line of sight
10	401	211	Midpoint of wood building
11	0	0	Note: next to building antenna. 3 attempts.
12	0	0	Far end of wood building.3 attempts.
13	224	179	Line of sight metal building
14	258	213	Line of sight metal building
15	0	0	Far end metal building. 3 attempts.
16	0	0	Midpoint far side metal bldg. 3 attempts.
17	343	190	Near line of sight

D. MIRA CHEWS RIDGE SITE

Table 24. MIRA Chews Ridge BGAN Data in Kbps

Distance from BGAN (Ft)	Upload Speed	Download Speed	Notes
0	447	200	5003 ft elevation
50	450	193	Flat line of sight
100	544	181	Flat line of sight

Distance from BGAN (Ft)	**Upload Speed**	**Download Speed**	**Notes**
150	481	180	Flat line of sight
200	517	242	Flat line of sight
250	572	245	Flat line of sight
300	360	105	Sharp increase in elevation by 9 feet, loss of line of sight
350	243	88	First reading 0, second reading as shown
400	0	0	3 reading attempts
450	0	0	5015 ft elevation. 3 reading attempts
500	0	0	3 reading attempts

E. FT ORD CONCRETE TEST RANGE FIELD TESTS

Table 25. Ft Ord Jetpack Concrete Test Range Data in Kbps

Distance (Ft)	Upload Speed	Download Speed	Notes
0	740	1179	
100	760	1751	
200	1048	1316	
300	1008	1367	
400	1254	1179	
500	949	440	
600	602	138	
700	531	135	
800	124	64	First attempt 0, second attempt as indicated
900	0	0	3 attempts
1000	0	0	3 attempts

Table 26. FT Ord BGAN Concrete Test Range Data in Kbps

Distance (Ft)	Upload Speed	Download Speed	Notes
0	182	220	
100	195	259	
200	190	200	
300	174	320	
400	45	201	
500	394	251	
600	128	94	
700	477	179	
800	619	167	Very strong gusts of wind
900	401	206	Very strong gusts of wind
1000	444	181	
1100	202	70	
1200	86	40	First attempt 0, second attempt 0, third attempt as indicated
1300	0	0	3 attempts

F. FT ORD WILDLAND TEST RANGE FIELD TESTS

Table 27. Ft. Ord BGAN Wildland Field Test Data in Kbps

Distance (Ft)	Upload Speed	Download Speed	Notes
0	280	159	Flat
100	291	164	Flat
200	306	176	Flat
300	381	159	Low shrubs
400	323	189	Low shrubs
500	320	111	Low hanging trees approximately 25 ft medium density
600	171	86	Medium density
700	107	90	Begin High density trees
800	0	0	High density trees, 3 attempts
900	0	0	Same
1000	0	0	Same

Table 28. Ft Ord Jetpack Wildland Field Test Data in Kbps

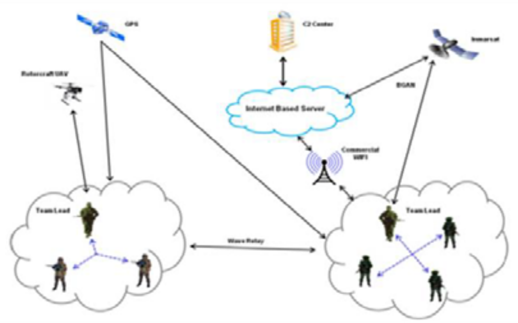
Distance (Ft)	Upload Speed	Download Speed	Notes
0	622	908	Flat
100	734	978	Flat
200	886	1120	Flat
300	845	1022	Low shrubs
400	901	1108	Low shrubs
500	765	843	Low hanging trees approximately 25 ft medium density
600	521	767	Medium density
700	112	272	High density
800	104	176	High density trees, 3

Distance (Ft)	**Upload Speed**	**Download Speed**	**Notes**
			attempts
900	43	82	Same. First attempt 0, second attempt as indicated
1000	0	0	Same. 3 attempts

APPENDIX B. QUAD DIAGRAM

Center for the Study of
Mobile Devices and Communications

Smart Phone Assisted Rapid Communication and Control System



Operational Capability

•Provides wireless network capabilities to teams in tactical and operational situations

• Facilitates centralized data capture and real time transmission of data and images/video

• Facilitates locally controlled aerial photographic and scanning capabilities with real time feed to the C2 center

• Facilitates GPS team locations in real time to C2 center

• Increases scene and location situational awareness to decrease decision cycles and improve decision making capabilities

Problem/Technical Approach

Problem

•Troops in the field or Emergency personnel in the field need an effective way to capture live scene based information and pictures and transmit them to a C2 center to promote rapid decision cycles and situational awareness in a tactical and operational environment

Technical Solution

•Implement a wireless smart phone network among small teams
• Utilize the photographic and texting capabilities of the smart phones and small tablet PCs to capture data
• Utilize wireless capabilities such as BGAN and Wave Relay to provide communications capabilities
• Utilize rotorcraft UAVs for aerial photographic capabilities

Milestones/Deliverables

Milestones

•Team cloud communication development and testing

•Centralized server and team cloud communications development and testing

•Rotorcraft UAV communications development and testing

•Full system integration, verification, validation and testing

Deliverable

•Field deployable smart phone assisted rapid communication and control system with full rotorcraft UAV integration and optimized communications platforms

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LIST OF REFERENCES

Alena, R., Evenson, D. & Rundquist, V. (2002). Analysis and testing of mobile wireless networks. *IEEE*, IEEEAC Paper 410.

Asche, M., & Crews, M. (March, 2012). *Utilizing Android and the cloud computing environment to increase situational awareness for a mobile distributed environment*. Naval Postgraduate School Master’s Thesis, US Department of Defense.

Bell, S., Jung, W., & Krishnakumar, V. (2010). WiFi-based enhanced positioning systems: accuracy through mapping, calibration, and classification. *ISA ’10*. November 2, 2010. San Jose, CA. ACM 978-1-4503-0433-7/10/11.

Bertolino, A. (2001). Software testing. Chapter 5, in *Guide to the Software Engineering Body of Knowledge SWEBOK* (v. 0.7), Software Engineering Coordinated Committee (Joint IEEE Computer Society-ACM Committee), April, 2001.

Biemer, S. (July, 2010). *The CONOPS and systems engineering*. Presentation at the Johns Hopkins University Applied Physics Laboratory, Baltimore, MD.

Boberg, J. (2008). Early fault detection with model based testing. *Erlang ’08*. September 27, 2008. ACM 978-60558-065-4/08/09.

Brooks, F. (1995). *The Mythical Man-Month: Essays on Software Engineering*. NY: Addison-Wesley.

Delmaro, M., Vincenzi, A. & Maldonado, J. (2006).A strategy to perform coverage testing of mobile applications. *AST’06*, May 2006. Shanghai, China. ACM 1-59593-085-X/06/0005.

Giadrosich, D. (1995). *Operations Research Analysis in Test and Evaluation.* Washington,DC.: AIAA.

Hughes Corporation. (2012). *Inmarsat BGAN Documentation*. www.hughes.com.

IEEE. (2004). *Software Engineering Body of Knowledge*. New York: Institute for Electrical and Electronic Engineers Computer Society Press.

Kasser, J. (2007). *A Framework for Understanding Systems Engineering*. Cranfield: Booksurge Publishing.

Kossiakoff, A. & Sweet, W. (2011). *Systems Engineering Principles and Practice*. NY: Wiley.

Nguyen, M., Waeselynck, H., & Riviere, N. (2008). Testing mobile computing applications. *WODA Workshop on Dynamic Analysis* July 21, 2008. ACM 978-1-60558-054-8/08/07.

Pan, J. (2012). *Software testing*. Presentation at Carnegie Mellon University http://www.ece.cmu.edu/~koopman/des_s99/sw_testing/index.html

Phelps D. Su, M., & Thulasiraman, K. (2010). Distributed testing and diagnostics in a mobile environment. *IWCMC '10*, June 28 – July 2, 2010, Caen, France. ACM 978-1-4053-0062-9/10/06.

Pressman, R. (2010). *Software Engineering: A Practitioner's Approach*. NY: McGraw Hill.

Sprigg, L., Krzystan, B., & Ziarco, J. (May, 2011). *System test and evaluation: test laboratory design and definition*. Presentation at the Johns Hopkins University Applied Physics Laboratory, Baltimore, MD.

Viana, A., Maag, S., & Zaidi, F. (2011). One step forward: linking wireless self organizing network validation techniques with formal testing approaches. *ACM Computing Surveys*, Vol. 43, No. 2.

Wasson, C. (2006). *Systems Analysis, Design, and Development*. NY: Wiley.

Yousef, K., & O'Neill, E. (2008). Preliminary evaluation of a remote collaborative environment. *CHI Proceedings* April 5 – April 10, 2008. ACM 978-1-60558-012-8/08/04.

Zhifang, L., Bin, L., & Xiaopeng, G. (2010). Test automation on mobile device. *AST 2010*. Cape Town South Africa. ACM 978-1-60558-970-1/10/05.

Ziarco, J. & Krzystan, B. (May, 2011). *Defining test sites*. Presentation at the Johns Hopkins University Applied Physics Laboratory, Baltimore, MD.

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